BC hydro

Integrated Resource Plan

Appendix 3A-3

2013 Resource Options Report Update

Environmental Attributes Review and Update

FINAL REPORT

2010 BC HYDRO RESOURCE OPTIONS UPDATE
REVIEW AND UPDATE OF ENVIRONMENTAL ATTRIBUTES

Prepared for:

BC hydro

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April 2011

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STATEMENT OF LIMITATIONS

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EXECUTIVE SUMMARY

As a part of the BC Hydro's 2010 Resource Options Report/Update, the environmental attributes used to characterize the energy generation resource options, were updated.

OBJECTIVES OF THE STUDY

The two key objectives of the work presented in this document were to:

1. Build upon the environmental attributes that BC Hydro developed for the 2006 IEP, and integrate new knowledge and information to create attributes appropriate to a provincially scaled planning study and recognizing the uncertainty of many of the energy generation resource options (ROs); and

2. Populate the environmental attributes for each of the potential resource options considered for the 2011 IRP.

APPROACH

The general approach to developing, preparing and presenting the environmental attributes is summarized as follows:

1. Reviewed environmental attributes (for example from the 2006 IEP/LTAP) and their applicability to this project, provincially scoped data sources, and the BC Hydro databases for resource option mapping (ROMAP);
2. Developed a revised and expanded set of attributes based on literature review and a set of criteria for selecting attributes;
3. Evaluated and selected attributes, based on internal review by BC Hydro, and external review by provincial ministries;
4. Developed a database of the selected attributes for the province;
5. Utilized the footprints developed for the resource options recognizing the inventory level nature of many of the resource options;
6. Applied the attributes to the BC Hydro database for ROMAP to populate environmental attributes for each resource option; and
7. Developed the environmental attributes such that they can be summed across resource options including power lines and access roads in the portfolios that BC hydro will develop as a part of the 2011 IRP.

CRITERIA

The evaluation criteria for the attributes are:

- Available at a high level provincial scale,
- Science-based and defensible,
- Measurable in a "quantity" based approach that will facilitate comparison across resource options,
- Representative of a specific biophysical resource,
- Existing or easily acquired data, and
- Easily understood by BC Hydro users, stakeholders and First Nations.

Each proposed attribute was evaluated against the criteria, and a set of attributes meeting these criteria was tested for use in this project.

ATTRIBUTE OVERVIEW

A revised and expanded set of attributes were developed based on the approach and criteria above. The most significant updates were made to the Land and Water attributes. New attributes were developed and Water was subdivided into Freshwater and Marine.

The attributes for air contaminant and greenhouse gas (GHG) emissions were not significantly changed from the previous BC Hydro studies.

The attributes by major attribute category (Land, Freshwater, Marine, and Air) are listed below:

- Land: Net Primary Productivity, Conservation Priority Species, and Linear Disturbance (remoteness),
- Freshwater: Riparian Footprint, Aquatic Footprint (reservoir area & affected stream length), and Priority Fish Species,
- Marine: Bathymetry, Valued Ecosystem Features, and Commercial Bottom Fisheries, and
- Air: Air Contaminants, and GHG Emissions.

The Land, Freshwater and Marine attributes were selected to provide a quantitative analysis of the footprint of resource options including power lines and access roads in terms of ecosystems, species and, where available, landscape context, through a provincial level attribute. This relationship was not as directly applicable to air contaminants and greenhouse gases which, as directed by BC Hydro, focused on the stressors (emissions) rather than impacts. Table E-1 presents a summary of the attribute

description, rationale, data sources and classifications for each major attribute category. Table E-2 classifies the attributes into ecosystems, species, and landscape context attributes.

In order to populate the potential resource options with environmental attribute data:

- Land, Freshwater and Marine attribute classification maps for the Province were developed in GIS, and
- Rates of air contaminants and GHG emissions (tonnes/GWh/year) were estimated for each potential resource option based on the generation technology.

APPLICATION

The environmental attributes were populated for the potential resource options, by either:

- the intersection of the physical footprint with the environmental attribute maps for physically based attributes (primarily Land, Freshwater and Marine); or
- the application of an emission rate (dependant on the resource option and technology) in relation to energy generation (GWhr/year) for activity based attributes (Air Contaminant & GHG Emissions)

Physical Footprints and Attributes

The accuracy of the underlying physical and spatial data was considered when relating the RO footprints and the environmental data, since it was recognized that:

- The resource options are spatially represented as point locations in a geographical information system (GIS) database (ROMAP).
- The potential resource option footprints, technical attributes and locations are, in most cases, conceptual and based on inventory level data. In some cases precise location information is available for resources such as Site C and Resource Smart.
- The environmental attribute source data used to develop the GIS environmental attribute datasets also varies with respect to data completeness, confidence and spatial accuracy.

In recognition of the above, a buffer area in which the physical footprint of a potential resource option could potentially be located was established. This was referred to as a 'probability envelope', which varied based on the resource option and its associated level of data confidence. The ROMAP database includes estimated footprints for the at-gate (generation site), road, and power line of each potential resource option.

The physically based environmental attributes for the resource options including power lines and access roads were populated as follows:

- The resource option physical footprint probability envelopes were intersected in GIS with the environmental attribute datasets to produce probability envelope values for each attribute and resource option.
- Each attribute value was then weighted by the ratio of the estimated physical footprint to the probability envelope area to populate the environmental attributes for each resource option. This limited the total area for each attribute to less than or equal to the estimated footprint.

This method resulted in a dataset of environmental attributes appropriate to the level of accuracy of this study.

Activity Footprints and Attributes

The estimated emissions rates for air contaminants & GHG, specific to each resource option, where a function of the energy generated in a year. The product of the emission rate and annual energy generation was used to estimate the annual emissions in tonnes. Exceptions were made for some resource options, such as Site C, where more detailed data was available.

SUMMARY AND RESULTS

Environmental attributes were developed and updated to enable the characterization the environmental attributes categories (Land, Freshwater, Marine and Air) for the resource options presented in the 2010 BC Hydro Resource Options Update. The attributes were developed to be applicable and appropriate at a provincial scale and inventory level, be science based and defendable, as well as consider the BC Hydro energy generation/transmission portfolio analysis.

Environmental attribute GIS datasets were developed for each spatially based attribute. These GIS datasets were intersected with the ROMAP resource option physical footprints using a probability envelope to account for data uncertainties.

Air contaminants and GHG emissions rates were estimated based on the resource option (and associated technology assumed for the IRP) and annual emissions were estimated for each applicable resource option.

The project has resulted in a dataset of environmental attributes for all the potential resource options including power lines and access roads that can be summed across resource options and used as input to BC Hydro's portfolio analysis to characterize the potential portfolios being considered by BC Hydro.

Table E-1: Summary of the Attributes

Attribute	Description	Rationale	Data Sources	Measure & Classifications
Land Attributes				
Net Primary Productivity	Net Primary productivity (NPP) is a measurement of plant growth, based on the quantity of carbon absorbed and stored by vegetation.	This is a quantitative measure that allows comparison between disparate ecosystems. It meets criteria for inclusion as a measure of the relative productivity of an area. It can be considered as a coarse-scale surrogate measure of biodiversity, with areas of higher primary productivity more likely to support a larger diversity of species.	Natural Resources Canada, Centre for Remote Sensing (used for Biodiversity BC Atlas)	Hectares (ha) within three classes of productivity ($gC/m^2/yr$): Low 0-<69 Med 69-<369 High > 369
Linear Disturbance Density	Linear density, or remoteness, is a measure of the degree of disturbance of an area (and its fragmentation) and its relative value to terrestrial wildlife, based on length of linear infrastructure per area of land.	This is a quantitative measure that meets criteria for inclusion as an attribute. Linear density categories range from urban/suburban to remote and indicate relative habitat value to large terrestrial mammals. Large terrestrial mammals can be considered an 'umbrella' species, in the sense that remote areas that are more likely to support these species are also likely to support a suite of other species	GeoBC, Digital Road Atlas: https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=45674&recordSet=ISO19115, BC Hydro Transmission Lines. Rail Lines	Hectares (ha) within four classes: Sub-urban and urban[a] (2.2 km per km^2 and higher) Rural (0.6 to 2.2 km per km^2) Remote (0.2 to 0.6 km per km^2) Wilderness (<0.2 km per km^2)
High Priority Species Count	Count of highly ranked species or priority species, likely to occur on any given hectare in the province, represented by percentile. Highly ranked species are those ranked 1 to 3 in the BC MOE Conservation Framework.	This is a species measure that combines spatial distribution and conservation status (which is a component of the determination of the priority ranking for each of 3 goals in the Conservation Framework). Species counts are arranged into percentiles to allow easy comparisons from one site to another. This measure meets all criteria for inclusion as an attribute. Higher percentiles correspond to higher counts of high priority species.	Prov. of BC Hectares BC dataset: High Priority Species Count Percentile	Hectares (ha) within five classes of percentiles binned into 20% increments: 0 to 20 20 to 40 40 to 60 60 to 80 80 to 100

[a] Includes utility corridors.

Freshwater Attributes				
Reservoir Aquatic Area	Reservoir area.	Construction and operations of reservoirs could affect aquatic habitat positively or adversely depending on the particular habitat system in question.	1. Site C, BC Hydro	Area (ha)
Affected Stream Length	Diverted stream reach "Diversion Reach"	Construction of a weir/dam or operations of a weir/dam will alter flow downstream of the structures, potentially affecting aquatic (fish) habitat	1. Site C, BC Hydro 2. Run-of-River (based on estimated penstock length), KWL 2010	Length (km)
Riparian Footprint	Riparian widths for streams at road and transmission line crossings will be based on a combination stream order and prescribed riparian setbacks based on channel widths that generally correspond with Stream Order identification.	Stream Order is a method used to describe the relative size of a stream or reach within a stream network. However, Stream Order does not correspond to specific riparian setbacks, hence the inclusion of information from other pertinent resources.	1.Stream Order classification & definitions. 2.BC Riparian Management Area Guidebook. 3. Establishing Fisheries Management and Reserve Zones in Settlement Areas of Coastal BC (DFO, 1997).	Hectares (ha) of Riparian Footprint within setback classes: Stream Order 1 = 30 m setback Stream Order 2 = 30 m setback Stream Order 3 = 40 m setback Stream Order 4 = 50 m setback Stream Order 5 = 70 m setback Stream Order ≥ 6 = 100 m setback
Priority Fish Species	Utilizing priority fish species that have been identified for conservation in the Province of BC through the BC Conservation Framework initiative.	The greater the number of priority species that inhabit a given area, the greater the species richness, implying greater heterogeneity of habitat. Low species richness can also be expressed as a lack of, or reduction in, biodiversity (measure of the health of ecosystems).	1. BC Conservation Framework – Conservation Priorities for Species and Ecosystems (2009) 2. Species Range GIS data (Wild Salmon Policy and MAPSTER databases, DFO) 3. BC 1:50,000 Watershed Atlas Data	Hectares (ha) within the classes: 1 to 10 species 11 to 20 species 21 to 30 species 31 to 38 species

Marine Attributes				
Bathymetry	Water depth classes	These depth classes influence seabed community composition and productivity	Canadian Hydrographic Service (CHS) 500m gridded digital bathymetry model data	Hectares (ha) within each of the following zones: 1.Photic Zone 0-20m 2.Shallow Zone >20-200m 3.Deep Zone >200-1000m 4.Abyssal Zone >1000m
Valued Ecological Features	A group of nine marine habitats of acknowledged high ecological value: • Protected Areas • Rockfish Conservation Areas • Coastal Estuaries • Salt Marsh Areas • Eelgrass Areas • Canopy Kelp Beds • Sponge Reef Areas • Important Bird Areas • Herring Spawning Areas	These habitats are usually identified as valued ecosystem components (VECs) in marine environmental assessment processes	**GeoBC (ILMB)** (www.geobc.gov.bc.ca) ShoreZone Data • Eelgrass • Canopy kelps • Salt marsh • Coastal estuaries Marine Protected Areas Ecological Reserves Herring Spawning Areas (http://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=3855&recordSet=ISO19115) **DFO** Rockfish Conservation Areas (http://www.pac.dfo-mpo.gc.ca/gis-sig/themes-eng.htm) Sponge Reef Areas (http://www.canbcdw.pac.dfo-mpo.gc.ca/ows/imf.jsp?site=mapster) **Canadian Wildlife Service** Known Estuaries of BC (Kenyon et al. 2007) **Bird Studies Canada** Important Bird Areas (http://www.ibacanada.com/contact.jsp?lang=en)	Hectares (ha) within each of the following classes No Valued Ecological Features 1 Valued Ecological Features 2-3 Valued Ecological Features >3 Valued Ecological Features

Key Commercial Bottom Fishing Areas	Seabed areas where benthic species harvested with fixed gear (longline or traps) as well as benthic trawl gear including • Crab (trap) • Prawns (trap) • Sablefish (trap) • Shrimp Trawl • Groundfish (trawl) • Groundfish (hook and line) Commercial catch and effort for these fisheries are mapped as 4x4km gridded areas of relative catch and effort	Fixed gear (trap, longline) and trawl fishing areas are relatively static relatively static and reflect areas of concentration of the target species. These gear types also present the highest risk of fisheries interactions with offshore power generation.	DFO – Mapster website http://www.canbcdw.pac.dfo-mpo.gc.ca/ows/imf.jsp?site=mapster	Hectares (ha) with commercial catch in each of the following Categories Class 1. No Bottom Fisheries Class 2. 1 Bottom Fishery Class 3. 2-3 Bottom Fisheries Class 4. >3 Bottom Fisheries
Air Attributes				
Air Contaminants	- Sulphur dioxide - Oxides of nitrogen - Carbon monoxide - Volatile organic compounds - Fine particulates - Mercury	Commonly referenced and accepted air contaminants that apply to energy resource options.	Various industry references / sources -rates of emissions for resource options and the technology assumed for the IRP.	Annual Tonnes (t) of: - SOx - NOx - CO - VOC - $PM_{2.5}$ & PM_{10} where avail., PM_{Total} - Hg
Greenhouse Gases (CO_2e)	Carbon dioxide equivalents (CO_2e) for all major GHGs	Commonly referenced in relation climate change.	Various industry references / sources -rates of emissions for resource options and the technology assumed for the IRP.	Annual Total tonnes (t) of CO_2e

Table E-2: Summary of Major Attribute Categories – Land, Freshwater and Marine Attributes

Attribute	Ecosystem/productivity	Species/habitat	Landscape Context
Land	Net Primary Productivity	Conservation Priority Species	Linear Disturbance (remoteness)
Freshwater	Riparian Footprint Aquatic Footprint	Priority Fish Species	Linear Disturbance[a]
Marine	Bathymetry	Valued Ecosystem Features Commercial Bottom Fisheries	Not applicable

[a] Linear disturbance is considered a measure for both land and freshwater attributes, however it is documented only in the land attributes section of the report.

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1.0 INTRODUCTION

1.1 INTRODUCTION

British Columbia's new *Clean Energy Act* (CEA) requires BC Hydro to prepare a long-term, integrated resource plan (IRP) by November 2011 for government review and approval. The 2011 IRP will describe BC Hydro's long-range plan for acquiring generation, transmission and demand-side management resources to meet customers' anticipated electricity needs. As a component of the planning process, BC Hydro will be evaluating the broad environmental implications of the resource options under consideration for the long term supply of electricity based on existing environmental conditions. The work presented in this report was conducted for Energy Planning and Procurement within BC Hydro in support of developing environmental attributes to facilitate and support the comparison of portfolios within the planning process.

BC Hydro has undertaken an update of information, including environmental attributes that is used for evaluating potential resource options including power lines and access roads. A targeted update of the attributes data was undertaken for the 2008 Long Term Acquisition Plan (LTAP). A full update, including an examination of socio-economic and environmental attributes, took place in 2005 for the 2006 Integrated Electricity Plan (IEP). The list of resource options that will be reviewed in the 2010 update include: biomass (biogas, MSW, and wood-based), capacity options, coal with carbon capture and storage, demand-side management, geothermal, in-stream, large hydro (Site C Clean Energy Project only), ocean (wave/tidal), pumped storage, run-of-river hydro, resource smart, solar, storage technologies, thermal (natural gas), transmission options and wind (on/off shore).

For integrated resource planning purposes, BC Hydro must first develop a load forecast to determine what BC's expected domestic electricity requirements are over the next 20 years. The load forecast is then compared to existing electricity supply to determine where any shortfall (or gap) in electricity will be over the planning timeframe. Bundles of supply and demand-side resource options (portfolios) are identified to fill this gap, and analyzed as part of the IRP process. The 'portfolios' will be designed to address electricity planning objectives such as reliability and to meet relevant objectives in the CEA. The analysis will track environmental factors along with technical, financial, and economic development factors to assist in understanding the broad implications of various portfolios.

This report presents a brief overview of the environmental attributes, the criteria used for selection, a description of the selected attributes, a discussion of the resource options and their land and water footprints, and an overview of the results of the analyses of the resource options with the attributes.

1.2 PROJECT OBJECTIVE

BC Hydro's goal is to update the environmental attributes, for land, air, water and climate, that are used by energy planners to better understand and characterize the resource options portfolios. As with the 2006/2008 IEP/LTAP, the environmental and economic development attributes will be used to characterize the resource options portfolios, rather than as a screening tool in selecting portfolios.

Since there is generally limited data regarding both the "potential" energy resource options and the potentially affected land, water and air environments, the environmental attributes are intended to be representative of the resource options and to characterize them with respect to key environmental considerations to inform BC Hydro energy planners, First Nations and stakeholders. BC Hydro has advised that the level of detail associated with the attributes data is not expected to be as precise as would be required to support an environmental assessment or permitting process for a specific resource option project, nor are the attributes intended to address land use and land use planning considerations which are outside of BC Hydro's scope.

The objective of the work presented in this document is to build upon the environmental attributes, that BC Hydro developed in 2006, and integrate new knowledge and information to create attributes appropriate to a provincially scaled planning study.

1.3 PROJECT APPROACH

The general approach to developing, preparing and presenting the environmental attributes is summarized as follows:

1. Reviewed environmental attributes (for example from the 2006/2008 IEP/LTAP) and their applicability to this project, provincially scoped data sources, and the data bases for resource options (the BC Hydro data set "ROMAP"),
2. Developed a revised and expanded set of attributes based on the literature review and a set of criteria for selecting attributes,
3. Evaluated and selected attributes, based on internal review by BC Hydro, and external review by provincial ministries (BC Hydro's consultation program is ongoing),
4. Developed the data base set of the selected attributes for the province, and
5. Developed the footprints for the resource options,
6. Reviewed the attributes within the BC Hydro data base for resource options (ROMAP) and revised as necessary to provide reasonable results, and
7. Summarized the results of the assessment of the resource options with the selected attributes.

The methodology for the development of individual attributes is discussed in the descriptions for the attributes in Sections 4, 5, 6 and 7.

1.4 RESOURCE OPTIONS

The following resource options were considered as a part of the environmental attributes update and dataset population:

- Biomass (Biogas),
- Biomass (MSW),
- Biomass (Wood Based),
- Geothermal,
- Large Hydro,
- Pumped Storage,
- Resource Smart,
- Run of River Hydro,
- Solar,
- Thermal (Natural Gas),
- Thermal (Coal with Carbon Capture & Storage),
- Transmission,
- Ocean Tidal,
- Ocean Wave,
- Wind (Onshore), and
- Wind (Off Shore).

Note that access roads and power lines were included in the environmental attributes dataset.

2.0 REVIEW AND DEFINITION OF ATTRIBUTES

2.1 BACKGROUND AND DEFINITIONS

Previous work undertaken by BC Hydro has considered environmental attributes, in which major attribute categories are a component of the environment such as land, water and air, and the individual attributes, as defined below, are indicators or measures which are used to represent each category (see Section 2.1.1). As an example, net primary productivity can be an attribute for land. Different classes (i.e., low, moderate and high) are represented within the attributes. The term "attribute" has been used in this report similarly to how the term "indicator" has been used in other studies discussed below.

The development of attributes for this project was guided by attributes and indicators developed for previous assessments undertaken for energy planning within BC Hydro, and several state of the environment reporting initiatives undertaken by other provincial governmental and non-governmental agencies (BC Conservation Framework, Biodiversity BC and the Nature Conservancy). This section of the report provides a definition for an attribute, and a brief overview of BC Hydro and provincial approaches to attributes. More information on attributes and databases specific to the land, marine and freshwater attributes is presented in their respective sections.

Environmental attributes or indicators provide a measure of environment conditions and/or trends in environmental conditions, reflecting causes, processes or results of impacts on different aspects of the environment. Gabrielson et al (2003, p.5) describe an indicator as:

> "an observed value representative of a phenomenon of study. In general, indicators quantify information by aggregating different and multiple data. The resulting information is therefore synthesised. In short, indicators simplify information that can help to reveal complex phenomena."

Attributes and Indicators can be described within a framework that looks at the causes (drivers and pressures) and effects (state and impact) and in some cases responses of society to address issues. This Driver - Pressure - State - Impact - Response framework (DSPIR) (MOE 2007, Gabrielson et al 2003) forms a basis for classifying types of indicators.

The BC Ministry of Forests (MOF) in its State of the Forests reporting defines an indicator as:

> "A quantitative or qualitative variable used to describe a state or condition. When observed periodically, it shows a trend. It provides information that is factual, usually for a specific time and place". (MOF 2006, p. 21):

This definition of an indicator is consistent with that used by the Canadian Council of Forest Ministers and the Montreal Process Sustainable Forest Management indicator initiatives. Further, in its study, the MOF groups indicators into several complementary types: qualitative/quantitative; input, process, output, outcome; pressure, state, response (similar to the DSPIR framework noted above); and environmental, economic, social or institutional (MOF 2006, p. 22).

Choice of the type of attribute or indicator, as well as the specific attributes, is dependent on the objectives of the study being undertaken. As this study is focusing on high level attributes to characterize the environment, quantitative state, or condition, attributes were selected, reflecting the physical state or condition of the land, water or air environments. The attributes are intended to describe the existing environment rather than assess the impact of past activities or resources options on the environment.

Provincially scoped reporting using attributes or indicators has been prepared by the BC MOE (MOE 2006), and MOF (2006), as previously noted. *Reporting by the Fraser Basin Council* (Fraser Basin 2009, 2010) and the Georgia Basin addresses indicators for portions of the Province of BC, directed towards assessing environmental health (rather than the characterization of the environment) as a component of sustainability. Both the Fraser Basin and Georgia Basin studies benefit from more comprehensive databases for environmental health (such as air and water quality) than are available for other portions of the province.

The purpose of the State of the Forests report was to provide information to enable readers and the Ministry of Forests (now Ministry of Forests, Mines and Lands – MOFM&L) to assess progress in achieving sustainable forest management. As such, the selected indicators were focused on this objective and addressed both existing conditions and trends. The 2006 MOF report addressed indicators within the categories of environment, economic and social, governance and support. Within the environmental category, the indicators included ecosystem diversity, protected forests, ecosystem dynamics, species diversity and genetic diversity. The MOFM&L intends to develop additional indicators over time.

Reporting on the State of the Environment by the BC MOE (2007) focused on measuring the progress towards sustainability, and is intended to address trends in the indicators over time. It is designed to address the status of the province as a whole, rather than the status of specific projects located within the province, and thus the analyses are not necessarily spatial, which is a requirement for indicators being developed by BC Hydro to evaluate resource options. The MOE report considers broad categories of indicators, covering population and economic activity, air quality, water quality, climate change, contaminants, ecosystems, and species conservation.

2.1.1 BC Hydro Studies

For the purposes of long term planning, BC Hydro developed a set of attributes for the 2006 IEP/LTAP (BC Hydro 2006). For the 2006 study, the attributes of the environment were air and greenhouse gases, land, and water, and attributes, or variables to measure the attributes, were developed for each attribute. The land and water attributes were based on the aquatic or terrestrial footprint of the resource options (BC Hydro 2005). In 2006, the attribute for land effects was the hectares of land impacted by structures of the resource option (footprint of the generating facility, roads, transmission lines, pipelines and inundated areas for large hydro). For water in 2006, an area of aquatic habitat was estimated for some resource options.

In the resource options update for the 2008 LTAP, power lines and roads were not evaluated for many of the updated resource options. Land and water attributes were also not estimated for many of the updated resource options.

The approach used for the 2006 IEP/LTAP (and 2008 LTAP), which is based on developing environmental attributes for land, water and air, has been reviewed and refined for this project as a part of the 2010 BC Hydro resource options update. This project also introduces additional attributes for the marine environment, recognizing the increased potential for resource options (e.g., offshore wind, tidal, and wave) associated with marine ecosystems, as well as including access road and power lines for all resource options (where applicable).

3.0 CRITERIA FOR ATTRIBUTES

To guide the selection of attributes, the following set of criteria was developed in consultation with BC Hydro. The focus was to develop science-based attributes at a provincial scale that are consistent and defensible and will support the comparison of resource options for the BC Hydro decision making process. The evaluation criteria are:

- Available at a high level provincial scale,
- Science-based and defensible,
- Measurable in a "quantity" based approach that will facilitate comparison across resource options,
- Representative of a specific biophysical resource,
- Existing or easily acquired data, and
- Easily understood by BC Hydro users, stakeholders and First Nations.

The objective is to develop a high-level picture of the environmental characteristics of different resource options to inform long term electricity planning.

The following environmental screens for resource options pre-exist in the BC Hydro Resource Options Mapping (ROMAP) database:

- Resource options may NOT fall within a legally protected area, and
- The run-of-river resource options may NOT occur on a known salmon bearing reach of a stream (this does not include a resource option that may be developed on a non-salmon bearing reach of a stream but has road or transmission impacts through salmon bearing streams).

Each proposed attribute was evaluated against the set of six criteria, and a set of attributes meeting these criteria was tested for use in spatial analysis at a provincial scale. Development of the final set of attributes was iterative, based on internal review within BC Hydro, external review by provincial ministries, and the ease of use of the available data sets within a GIS based system. The list of attributes evaluated for use for this project is presented in Appendix A.

4.0 ATTRIBUTES – LAND, FRESHWATER AND MARINE APPROACH

A set of attributes for the land, air, freshwater and marine attributes categories has been developed through:

- Reviews of attributes previously developed by BC Hydro as well as other provincial organizations,
- Reviews of readily available data sets, and
- An internal (BC Hydro) and external (non-governmental organizations (NGOs) and provincial ministries) review process with knowledgeable professionals.

The objective for selecting the land, freshwater and marine attributes was to provide a characterization of three key components of the environment – ecosystems/productivity, species presence and quality of the existing environment (landscape context or disturbance) for each of the attributes. The rationale behind these three components for attributes reflects the approach taken in an environmental assessment where "vegetation resources" or ecosystems, and "wildlife resources" or species/habitat are assessed, supplemented by a characterization of the existing landscape disturbance.

For this project, the approach is to provide a quantitative comparison of the footprint of a resource option in terms of its ecosystems, species and, where available, landscape context, through a provincial level attribute. The relationship of the attributes selected to the rationale for selection is shown in Table 4.1 for land, freshwater and marine environments (See Section 8.0 for air attributes). The analysis of the resource options shows the area of the resource option within the classes for the attribute (e.g., the area (ha) of high net primary production).

Table 4-1: Summary of Major Attribute Categories – Land, Freshwater and Marine Attributes

Attribute	Ecosystem/Productivity	Species/Habitat	Landscape Context
Land	Net Primary Productivity	Conservation Priority Species	Linear Disturbance (remoteness)
Freshwater	Riparian Footprint Aquatic Footprint	Priority Fish Species	Linear Disturbance[a]
Marine	Bathymetry	Valued Ecosystem Features Commercial Bottom Fisheries	Not applicable

[a] Linear disturbance is considered a measure for both land and freshwater attributes, however it is documented only in the land attributes section of the report.

The rationale for each of the attributes is discussed in the following sections for land (terrestrial resources), freshwater and marine environments (sections 5.0, 6.0, and 7.0). Each section considers an overview of the approach and use of attributes in other projects/areas, a description of attributes and a summary table of attributes.

5.0 LAND ATTRIBUTES

5.1 INTRODUCTION

Land attributes consider the terrestrial footprint of the resource option site and the supporting infrastructure, such as the power line corridor and road access. In general, land attributes are relatively well advanced in BC and several land attributes have been developed through attribute or resource management initiatives, as noted in Section 2 and summarized below.

5.2 LITERATURE REVIEW

A synopsis of the data sources/projects in BC which were considered during the literature review for this project is presented below. The references provided guidance to the development of terrestrial attributes to allow a quantifiable comparison amongst potential resource options as part of the BC Hydro IRP. Appendix A provides a summary of potential attributes that were reviewed in the course of the environmental attributes study.

- BC Hydro professional expert advice,
- Biodiversity BC produced the Biodiversity Atlas of British Columbia in 2009, which presents 60 province-wide metrics spanning the categories of ecosystems, species, special elements of biodiversity, and disturbance or threats to biodiversity,
- The Nature Conservancy of Canada (2009) produced GIS based mapping products to prioritize the relative conservation value of nine watershed units in BC, including the Iskut-Lower Stikine, Upper Nass, Upper Skeena, Upper Peace, Bella Coola-Dean, Middle Fraser, Upper Fraser, Homathko-Klinaklini, and Thompson. Nature Conservancy measures included irreplacability, a relative biodiversity index, as well as measures of utility and human impacts,
- The Ministry of Environment (MOE) has recently developed a system for ranking species and ecosystems in terms of conservation priority called the Conservation Framework (BC MoE 2009). The framework includes three goals: to contribute to global efforts for species and ecosystems conservation; to prevent species and ecosystems from becoming at risk; and to maintain the full diversity of native species and ecosystems. As part of the Conservation Framework, a database that ranks the conservation priority of BC flora and fauna for each of these three goals has been created, and
- Hectares BC is a collaborative pilot project created under the Biodiversity BC partnership, which includes a number of government and non-governmental organizations. It is a searchable geospatial database of integrated and summarized natural resource information organized at a one hectare raster scale for the Province of BC. The BC Hectares website is the point of access for Conservation Framework information, along with the BC Species and Ecosystem Explorer

web application. Spreadsheets of species and ecosystem outputs are available on BC Ministry of Environment website.

5.3 LAND ATTRIBUTES

5.3.1 Net Primary Productivity

A net primary productivity (NPP) data set was selected to represent ecosystem productivity. NPP is a measurement of plant growth obtained by calculating the quantity of carbon absorbed and stored by vegetation (CFS 2010). NPP provides a means of quantitative comparison between disparate habitat types and can be related to biodiversity. As a general rule, areas with higher NPP values have a greater diversity of species and a greater intrinsic value to a larger range of biota. Biodiversity BC (2009) presented NPP data as one descriptor of ecosystems in the province.

Relative net primary productivity meets the criteria of being high-level provincial scale, science-based, and measurable in a quantity-based approach. It can be considered a coarse-scale correlate of species diversity and allows comparison across resource options. The dataset, produced from national data, is at a fairly coarse resolution of 5 x 5 km. It shows patterns of average net primary productivity on land across the province from 1960-2000 based on land cover present in 2000.

In terrestrial ecosystems, primary production is carried out mostly by vascular plants (with a small fraction coming from algae and non-vascular plants such as mosses and liverworts). In general, land with greater plant cover will have greater net primary productivity. The highest net primary productivity occurs in the forested areas of the province, with the lowest productivity in the alpine regions. (Biodiversity BC 2009). In a broad sense, low category NPP values correlate with features such as ice fields and exposed rock, and values categorized as high correlate with productive forest cover types such as coastal forests. However, unlike land cover mapping, NPP allows for comparison via a quantifiable score.

The NPP dataset was derived from an EALCO (Ecological Assimilation of Land and Climate Observations) model simulation based on a number of remote sensing Moderate Resolution Imaging Spectroradiometer (MODIS) and GIS datasets. It was prepared by Natural Resources Canada, Centre for Remote Sensing and used for, Biodiversity BC Atlas.

5.3.2 High Priority Species Count

The Hectares BC dataset High Priority Species Count Percentile was selected as the land attribute to represent species. This dataset is a combination of conservation framework rankings and spatial distributions of vertebrates, invertebrates, vascular and non-vascular plant species. The dataset includes only high priority species under the Conservation Framework (i.e., those ranked one to three). The count of highly ranked species likely to occur on any given hectare in the province is represented by percentile, which compares the number of species in one hectare to all other hectares. Higher percentiles indicate higher counts of priority species. For example, if a hectare is symbolized as belonging to the 60-80 percentile bin, it means that 60 per cent of hectares have a lower count of priority species and 20 per cent of the hectares have priority species counts that are higher.

Species ranges used to develop this data layer were derived via queries of data layers from the provincial Land Resource Data Warehouse and vary for each individual species modelled (pers. comm. Jeff Lounsbury). For example, the boreal chorus frog species range was derived from the Forest Districts, Ministry of Environment Regions, Regional Districts, and Biogeoclimatic Environmental Classification (BEC) datasets (pers.comm. Jeff Lounsbury, 2010).

The data layer is appropriate for use at a high-level provincial scale. It provides a coarse scale view of the distribution of conservation priority species across the province. The conservation framework methodology for ranking species is science-based and was developed with input from provincial environmental regulatory agencies. Species distribution information was also derived from provincial datasets. The species distribution data used in developing this data layer varies amongst species, and may be more accurate for some species than others. Species distribution data used in developing the High Priority Species Count Percentile layer was the best data available at the province-wide scale, and is appropriate as a coarse-scale description of species range. The species data from the Conservation Framework and other Ministry sources, which form the basis for Hectares BC analyses, are continuously revised as more precise datasets become available, however the changes between when the Hectares BC data was analysed (December 2009) and the present are considered minimal at a provincial scale. Species counts percentiles are quantity-based and will allow comparison across resource options.

5.3.3 Linear Disturbance Density

Linear disturbance densities provide information about the ecological context of any given site. Linear disturbance density can be used as an indicator of probable habitat use for large wide-ranging terrestrial mammals and can be used as measure of an areas relative value to terrestrial wildlife. Linear density is statistically related to large mammal habitat use (Jalkotzy et al. 2007) and linear density estimates have predictive power comparable to more detailed and costly habitat measures.

A linear disturbance dataset was derived from the following source datasets:

- Digital Road Atlas Database Model, and
- BC Hydro Transmission Lines- BC Hydro_TL_DEC08.

Linear disturbance density categories were defined as follows:

- Urban and Sub-urban (>2.2 km per km^2),
- Rural (0.6 to 2.2 km per km^2),
- Remote (0.2 to 0.6 km per km^2), and
- Wilderness (<0.2 km per km^2).

The previously mentioned data sets were combined to create a province-wide dataset on a one hectare grid. Linear disturbance density is science-based in the sense that it is a measurable quantity that is comparable across all terrestrial landscapes in the province and across resource options. Linear density, especially road density, has been statistically related to the habitat suitability of large mammals in the literature and is considered a reasonable measure of the relative value of land to large terrestrial mammals. The life requisites of large mammals wide-ranging mammals can act as an 'umbrella' for other wildlife values - large tracts of relatively undisturbed habitat is likely to also support a variety of other taxa.

Linear disturbance density is a relatively easy to understand metric, as the categories with lower linear densities are more valuable to a broader diversity of wildlife than higher densities: For example, the wilderness category is more valuable to wildlife than areas categorized as urban.

5.3.4 Summary Table

The rationale for the selection, the data sources and the classes are summarized for the three land environmental attributes in Table 5.1.

Table 5-1: Summary of Land Attribute, Including Rationale, Data Sources and Classifications

Attribute	Description	Rationale	Data Sources	Measure & Classifications
Net Primary Productivity	Net Primary productivity (NPP) is a measurement of plant growth, based on the quantity of carbon absorbed and stored by vegetation.	This is a quantitative measure that allows comparison between disparate ecosystems. It meets criteria for inclusion as a measure of the relative productivity of an area. It can be considered as a coarse-scale surrogate measure of biodiversity, with areas of higher primary productivity more likely to support a larger diversity of species.	Natural Resources Canada, Centre for Remote Sensing (used for Biodiversity BC Atlas)	Hectares (ha) within three classes of productivity ($gC/m^2/yr$): Low 0-<69 Med 69-<369 High > 369
Linear Disturbance Density	Linear density, or remoteness, is a measure of the degree of disturbance of an area (and its fragmentation) and its relative value to terrestrial wildlife, based on length of linear infrastructure per area of land.	This is a quantitative measure that meets criteria for inclusion as an indicator. Linear density categories range from urban/suburban to remote and indicate relative habitat value to large terrestrial mammals. Large terrestrial mammals can be considered an 'umbrella' species, in the sense that remote areas that are more likely to support these species are also likely to support a suite of other species	GeoBC, Digital Road Atlas: https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=45674&recordSet=ISO19115, BC Hydro Transmission Lines. Rail Lines	Hectares (ha) within four classes: Sub-urban and urban[b] (2.2 km per km^2 and higher) Rural (0.6 to 2.2 km per km^2) Remote (0.2 to 0.6 km per km^2) Wilderness (<0.2 km per km^2)
High Priority Species Count	Count of highly ranked species or priority species, likely to occur on any given hectare in the province, represented by percentile. Highly ranked species are those ranked 1 to 3 in the BC MOE Conservation Framework.	This is a species measure that combines spatial distribution and conservation status (which is a component of the determination of the priority ranking for each of 3 goals in the Conservation Framework). Species counts are arranged into percentiles to allow easy comparisons from one site to another. This measure meets all criteria for inclusion as an attribute. Higher percentiles corresponds to higher counts of high priority species.	Prov. of BC Hectares BC dataset: High Priority Species Count Percentile	Hectares (ha) within five classes of percentiles binned into 20% increments: 0 to 20 20 to 40 40 to 60 60 to 80 80 to 100

[b] Includes utility corridors

6.0 FRESHWATER ATTRIBUTES

6.1 INTRODUCTION

Activities which disturb the land, divert water, or are located in or adjacent to or cross water, have the potential to disturb aquatic ecosystems and fisheries resources. Biomass, customer cogeneration, and DSM options typically pose minimal risks to aquatic ecosystems. However, natural gas, coal, large hydro, run-of-river hydro, wind and geothermal projects all require infrastructure (e.g., weirs, access roads, pipelines, penstocks, transmission) that can impact aquatic resources (e.g., fish and fish habitat).

Given the range of resource options that could result in impacts to aquatic ecosystems, there is a need for freshwater attributes to assist in evaluating resource options. At the same time, measures describing risks to fish habitats from different resource options has been limited by a lack of existing information on proposed resource options and knowledge of links between physical changes caused by the resource projects and the productive capacity of fish habitat.

The attributes derived and implemented by BC Hydro in 2005 focused on the "surface area of aquatic habitat potentially affected by development" (combining several variants of an aquatic habitat-area-at-risk). Though this provides some value in determining aquatic 'footprint', key data gaps were acknowledged that could augment the attribute. These gaps include: 1) accuracy of physical data in the resource database; 2) accuracy of the prediction of aquatic habitat effects from physical data; and 3) comparability of predictions between different resource options.

The objective of the work described in this report was to improve utility of the water (freshwater) attributes and to build upon existing attributes through the integration of new, more refined data, specific to British Columbia's fisheries resource. The 2005 "Aquatic Habitat Area" attribute did attempt to incorporate fish presence/absence information (Sigma Engineering 2002), but did not include comprehensive biological information that would ultimately begin to address data gaps (specific to 2) in the preceding paragraph.

Geospatial inventory and mapping of British Columbia fisheries resource features has rapidly improved over the last decade. There are now a number of federal, provincial, and joint (federal, provincial, non-government) initiatives that provide valuable access to fish and fish habitat-related information/data to a widely dispersed and diverse group of users, which can be applied to address a diverse array of objectives. The discussion presented below provides a synopsis of the pertinent data sources/projects in BC, which were considered during the literature review for this project. Appendix A also provides a summary of attribute measures that were reviewed in the course of the study.

6.2 LITERATURE REVIEW

6.2.1 Fisheries Sensitive Watersheds and Watershed Evaluation Tool

Fisheries sensitive watersheds (FSWs) in British Columbia are an important social, economic, and ecological feature of the Province's landscape. To help conserve fisheries values within these watersheds, and consistent with the provisions provided under the *Forest and Range Practices Act* (FRPA) and the *Government Actions Regulation* (GAR), the Ministry of Environment (MOE) has drafted a procedure to evaluate and designate FSWs. This program is achieved by implementing the Watershed Evaluation Tool (WET), which is intended to provide provincial and regional "consistency" to the evaluation, and selection, of candidate FSWs.

The WET uses a series of indicators (or measures) to establish "fisheries value" and "watershed sensitivity value" for each of the 1:50,000 third order watersheds found within the coverage of the BC Watershed Atlas. Fisheries Values are assessed using the following indicators: 1) Biodiversity (fish species range, species richness, threatened or endangered species through Conservation Data Centre (CDC), special "regionally important" stocks); 2) First Nations Cultural Values; 3) Socio-economic Value. Watershed Sensitivity Values are assessed using indicators including: 1) Terrain Stability (% watershed with slope >60%; 2) Stream Channel Stability (channel length on stream channels with <8% gradient per unit area; 3) Level of existing Disturbance (% stream bank disturbed, road density, % watershed in disturbed state).

Though strong consideration was given to the Province's FSW program, it could not be entirely applied as a fisheries attribute measure for evaluating resource options. Rationale for this determination included: 1) the Province's FSW program takes into consideration social factors, which are excluded from the criteria; 2) the program has not yet been applied across the province, thus its full utility/strength has not been tested; and 3) the need for regional/local data/knowledge that is necessary for properly identifying FSWs. As an alternative consideration, components of the FSW program (i.e., Fish Species Range, Provincial Species at Risk, Species Richness, Fish Sensitivity) were extracted to attempt to create a "biodiversity" measure. However, due to the complexity of its development the "biodiversity" measure was not pursued further at this time.

6.2.2 Salmon Conservation Units (NCC/DFO)

Fisheries and Oceans Canada (DFO), in collaboration with the Nature Conservancy of Canada (NCC), have developed a methodology, which builds upon the federal government's *Wild Salmon Policy*, to identify, protect and conserve the biological diversity of the five Pacific Salmon species in British Columbia. The goal of the *Wild Salmon Policy* is to restore and maintain healthy and diverse salmon populations and

their habitats for the benefit and enjoyment of the people of Canada in perpetuity. This policy goal is intended to be advanced by safeguarding the genetic diversity of wild salmon populations, maintaining habitat and ecosystem integrity, and managing fisheries for sustainable benefits. Conservation of wild salmon and their habitat is the highest priority for resource management decision-making. Wild salmon are being maintained by identifying and managing "Conservation Units" (CUs) that reflect their geographic and genetic diversity. A CU is a group of wild salmon sufficiently isolated from other groups that, if lost, is very unlikely to recolonize naturally within an acceptable timeframe. The Conservation Unit is a tool for identifying and describing diversity at a level for practicable implementation of the *Wild Salmon Policy*. Data is packaged as a database and accompanying geographic information system (GIS) that enables visual representation of identified Conservation Unit for each Pacific Salmon species.

6.2.3 Ecological Aquatic Units (NCC/BC Provincial Government)

Ecological Aquatic Unit (EAU) BC is a hierarchical classification of BC's freshwater ecosystems. It is a spatially explicit classification designed to aid in the management and conservation of BC's freshwater ecosystems and their associated biodiversity. EAU BC quantifies the interaction between freshwater species distribution and their ecosystem's physical habitat, and environmental processes. It defines what is currently known about freshwater ecosystems and their abundance and distribution across the Province. It is packaged as a database and accompanying geographic information system (GIS) that enables the classification and its underlying data to be queried and viewed at multiple spatial scales. EAU BC was developed with the following functions at the forefront (Ciruna et al., 2007):

- Provide an environmental characterization of freshwater ecosystem types in BC that will aid in their specific conservation and management,
- Provide a spatially explicit data management system for freshwater ecosystems in BC,
- Enable regional comparisons of freshwater ecosystems,
- Help inform species/habitat relationships, and
- Provide a stratification framework for freshwater inventory/monitoring programs and state of the environment reporting on freshwater ecosystems in BC.

6.2.4 Salmon Recovery Planning

Salmon Recovery Plans have been initiated under the *Pacific Salmon Endowment Fund* or the *Species at Risk Act* (SARA). The primary purpose of these recovery plans is to identify and set priorities for activities required to achieve the recovery goals for a specific watershed and its fish stocks. Recovery strategies and action plans are required when species are listed under SARA. Recovery plans may, however, be prepared for COSEWIC (Committee on the Status of Endangered Wildlife in Canada) listed aquatic species that have not been formally listed under SARA.

6.2.5 Watershed-based Fish Sustainability Plans

Boundaries of watersheds where Watershed Based Fish Sustainability Planning (WFSP) processes have been initiated under the WFSP process developed jointly by DFO and the BC Provincial Government in 2001. Details of this planning process are described in the document "*Watershed-Based Fish Sustainability Planning: Conserving BC Fish Populations and Their Habitat: A Guide Book for Participants*" co-published by BC MOE and DFO.

6.2.6 Conservation Framework

The Conservation Framework provides a set of decision support tools to enable collaboration between government and non-government resource managers and practitioners using clearly defined criteria to:

- Prioritize species (and ecosystems) for conservation, and
- Determine the most appropriate and effective management actions.

To better manage for species and ecosystems of conservation concern, British Columbia developed the Conservation Framework to optimize allocation of resources. This is an approach that:

- Is based on specific goals to guide conservation efforts for species of conservation concern;
- Addresses the issue of jurisdictional rarity (where a species' range "drifts" across a jurisdictional boundary),
- Is proactive for species that are not yet at risk but are experiencing serious downward population trends,
- Adequately addresses British Columbia's stewardship responsibility for globally important species, and
- Is based on the best available scientific information to quickly and transparently prioritize species and assign them to appropriate management actions.

6.2.7 British Columbia Conservation Data Centre

The British Columbia Conservation Data Centre (CDC) systematically collects and disseminates information on plants, animals and ecosystems (i.e., ecological communities) at risk in BC. This information is compiled and maintained in a computerized database, providing a centralized and scientific source of information on the status, locations and level of protection of specific organisms and ecosystems. The CDC is part of the Environmental Stewardship Division (ESD) in the BC Ministry of Environment. It is also part of NatureServe Canada and NatureServe, national and international organizations, respectively, of cooperating

Conservation Data Centres and Natural Heritage Programs using the same methodology as the CDC, to gather and exchange information on threatened elements of biodiversity.

6.2.8 Community Mapping Network

The main objective of the Community Mapping Network (CMN) is to promote planning sustainable communities. Many sensitive habitats such as urban and smaller rural watercourses, riparian areas and wetlands remain unknown, poorly understood, and/or suffer from impacts of human development. Methods provided through CMN reflect a novel set of tools to explore and promote awareness of these habitats by mapping their location and inventorying their attributes. The awareness and commitment to local watercourses and other sensitive habitats is an important process created through co-operation of local communities, First Nations, municipalities, planners, and managers. Community mapping methods comprise a set of tools and methods that can be used to help conserve fisheries, wildlife and aquatic habitat resources throughout British Columbia.

The CMN integrates data from many sources and makes it accessible through a user friendly mapping system. There are many uses of the information including watershed planning, research, impact assessment, and community planning to name a few.

6.2.9 Fisheries and Oceans Canada (DFO) Data Warehouse

The DFO Pacific Region Data Warehouse is comprised of a number of sources. Two of the sources are:

1. Mapster (V. 2.2) is an internet-based GIS application that provides access to fish and fish habitat-related information for a widely dispersed and diverse group of users. Over 200 datasets from British Columbia and the Yukon Territory can currently be viewed or queried through MAPSTER's interactive map interface. These data represent specific themes such as fish species presence and distribution etc., and
2. The Habitat Wizard GIS-database creates maps, produces summary reports, and compiles the most recent information regarding British Columbia lakes and streams and the fish that inhabit them, including fish species range, stream physical data, stocking records, and depth maps for over 2,500 lakes.

6.3 FRESHWATER ATTRIBUTES

6.3.1 Aquatic Footprint

Two attributes for aquatic footprint have been included: Reservoir Area and Affected Stream Length.

The rationale for including an attribute such as this is that reservoir development and reservoir operation may have positive or adverse affects on habitat. The length of the watercourse with natural flows altered as

a result of reservoir (or headpond) development and operation typically has an adverse effect on aquatic habitat; the magnitude of effect generally attributed to fish bearing status and habitat loss.

A summary on how Reservoir Area and Affected Stream Length was calculated is presented in Section 9 of this report.

Riparian Footprint

Stream order is a method used to describe the relative size of a stream or reach within a stream network. The uppermost segments of a stream system are referred to as first-order streams. These segments occur between the origin of the stream and the point where it joins another stream. In other words, the first-order segments of a stream network cannot be located downstream of a convergence or fork. The convergence of two first-order streams produces a second-order stream, and similarly, a third-order stream is created by the convergence of two second-order streams. In this fashion, stream order becomes progressively higher moving downstream in a given system. Stream order can only be elevated by the joining of two streams equal in order and is unaffected by streams of lower order. For example, the level of a third-order stream is not changed when joined by any number of first or second-order streams and only becomes a fourth-order stream when joined by another third-order stream.

Although stream order can be a useful index to indicate relative stream size, in that it roughly correlates to the upstream drainage area and hydrological potential, it is not an accurate representation of stream size. Subsequently, there is potential for wide variation in stream size within a given stream order level. For example, a second-order stream comprised of two very short first-order tributaries might have an extremely small drainage area and discharge rate when compared to an adjacent second-order stream with a large number of relatively long first-order streams entering it. Similarly, a second-order stream could have a smaller catchment area and discharge rate than many first-order streams.

Prescribed setbacks from streams were developed using stream order as the key identifier. The "*BC Riparian Management Area Guidebook*" (Forest Practices Code 1995) and the document "*Establishing Fisheries Management and Reserve Zones in Settlement Areas of Coastal British Columbia*" (Millar et al 1997), provide solid rationale for riparian setbacks on particular sized watercourses, however they require information on stream width and fish presence. Since there is no province-wide data set on stream width and data is limited on fish presence, stream order, which is available for all streams in BC and correlates with the size of a river, was used as a Proxy for stream width. Stream ordering is a process of identifying and grouping stream segments and their corresponding watersheds in terms of size and complexity, but does not typically correspond directly to specific riparian setbacks, hence the inclusion of information from other documents.

The setbacks are as follows:

- Stream Order 1 = 30 meter setback,
- Stream Order 2 = 30 meter setback,
- Stream Order 3 = 40 meter setback,
- Stream Order 4 = 50 meter setback,
- Stream Order 5 = 70 meter setback, and
- Stream Order ≥ 6 = 100 meter setback.

A dataset of provincial estimated riparian setbacks was prepared based on the stream order and the corresponding assumed setbacks shown above. A summary of how riparian footprint was calculated is presented in Section 9 of this report.

6.3.3 Priority Fish Species (Species Diversity)

Through the Conservation Framework's (2007) "Conservation Prioritization and Action Sorting Tool", a Provincial list of native priority fish species was tabulated. The species output was created by utilizing five criteria: 1) priority species ranking at both the global and provincial levels (determined by NatureServe and BC Conservation Data Centre); 2) species trend; 3) threat to species; 4) feasibility; and 5) stewardship responsibility. Each species is assigned a priority rank based from these criteria; the criteria are applied to each species for each 'Goal' of the Conservation Framework initiative. It is intended that species conservation will receive attention and resources under the identified Goal in which it ranks the highest.

A list of 101 priority fish species were generated from the Conservation Framework prioritization tool. To develop a priority list of fish species that could be effectively used at a high level, an initial 'coarse' list of species was cross-referenced with:

- The BC Ministry of Environment list of Introduced (Exotic) freshwater fish in BC to confirm no exotic fish species were included in the species list (www.env.gov.bc.ca/ wld/fishhabitats/introduced),
- The BC Ministry of Environment list of Native Freshwater Fish in BC as a check to confirm species nomenclature (www.env.gov.bc.ca/wld/fishhabitats/native), and
- BC fish species range data (gathered from the Wild Salmon Policy and Mapster GIS databases [DFO]) to exclude species that have no associated provincial range data.

An output of 68 priority fish species was generated, which comprised solely of species of fish native to British Columbia, have been assessed and ranked by the BC Conservation Framework, and have associated species distribution (range) data for the Province.

To understand general distribution for all 68 priority species over the Province, species range data for each of the 68 species was integrated into a GIS model overlaying the Provincial 1:50,000 Watershed Atlas. The GIS output was a provincial watershed overlay of the distribution of all species. A conservative approach was implemented when applying the species range data – for any watershed that had greater than 25% coverage by a given species; the species was assumed to inhabit the entire watershed. Results of the mapping simulation produced a maximum of 38 fish species that would inhabit a given watershed in BC. A point to make here, although there are several watersheds that inhabit the maximum number of fish species (N=38), the simulation does not identify species composition. Thus, each watershed may have a different make-up of priority fish species from the 68 priority species mapped across the province.

6.3.4 Summary Table

The rationale for the selection, the data sources and the classes are summarized for the three freshwater environmental attributes in the table below (Table 6.1).

Table 6-1: Summary of Freshwater Attributes

Attribute	Description	Rationale	Data Sources	Measure & Classifications
Reservoir Aquatic Area	Reservoir area.	Construction and operations of reservoirs could affect aquatic habitat positively or adversely depending on the particular system in question.	1. Site C, BC Hydro	Area (ha)
Affected Stream Length	Diverted stream reach	Construction of a weir/dam or operations of a weir/dam will alter the flow downstream of the structures potentially affecting aquatic (fish) habitat.	1. Site C, BC Hydro 2. Run-of-River (based on estimated penstock length), KWL 2010	Length (km)
Riparian Footprint	Riparian widths for streams at road and transmission line crossings will be based on a combination stream order and prescribed riparian setbacks based on channel widths that generally correspond with Stream Order identification.	Stream Order is a method used to describe the relative size of a stream or reach within a stream network. However, Stream Order does not correspond to specific riparian setbacks, hence the inclusion of information from other pertinent resources.	1. Stream Order classification & definitions. 2. BC Riparian Management Area Guidebook. 3. Establishing Fisheries Management and Reserve Zones in Settlement Areas of Coastal BC (DFO, 1997).	Hectares (ha) of Riparian Footprint (ha) within setback classes: Stream Order 1 = 30 m setback Stream Order 2 = 30 m setback Stream Order 3 = 40 m setback Stream Order 4 = 50 m setback Stream Order 5 = 70 m setback Stream Order ≥ 6 = 100 m setback
Priority Fish Species	Utilizing priority fish species that have been identified for conservation in the Province of BC through the BC Conservation Framework initiative.	The greater the number of priority species that inhabit a given area, the greater the species richness, implying greater heterogeneity of habitat. Low species richness can also be expressed as a lack of, or reduction in, biodiversity (measure of the health of ecosystems).	1. BC Conservation Framework – Conservation Priorities for Species and Ecosystems (2009) 2. Species Range GIS data (Wild Salmon Policy and MAPSTER databases, DFO) 3. BC 1:50,000 Watershed Atlas Data	Hectares (ha) within the classes: 1 to 10 species 11 to 20 species 21 to 30 species 31 to 38 species

7.0 MARINE ATTRIBUTES

7.1 INTRODUCTION

Inventory and mapping of British Columbia marine features is not as well advanced or coordinated as terrestrial features, however there are a number of important federal and provincial initiatives that have advanced marine spatial resource mapping in recent years. This section briefly reviews the evolution of marine geospatial mapping in British Columbia and highlights recent initiatives.

In British Columbia the province has taken a lead role in inventory and mapping of near shore marine resources (ftp://ftp.gis.luco.gov.bc.ca/pub/coastal/rpts/BCBiophysicalShore-ZoneMapping.pdf)) since the 1980s, initially for the purpose of oil spill contingency planning. In addition, the province has led initiatives to inventory and map those coastal features and activities which fall under their jurisdiction (shellfish beds, aquaculture capability, foreshore lease areas). Federally, DFO has led initiatives to map fisheries resources (such as herring spawning areas) and commercial fishing activity (fishing effort and catch). Many of these initiatives were initiated before the advent of geospatial mapping tools and have subsequently been fitted to geospatial platforms.

The discussion presented below provides a synopsis of the data sources/projects in BC which were considered during the literature review for this project. Appendix A provides a summary of attributes that were reviewed in the course of the environmental attributes study.

7.2 LITERATURE REVIEW

7.2.1 Oceans Strategy

Wainright et al. (2007) provides an assessment and analysis of ocean information data holdings to support oceans strategy and planning in British Columbia. This project summarized the available data, identified the data custodian and conducted an assessment of holdings based on defined criteria (completeness, up-to-date, quality, accessibility and suitability). The analysis revealed that very few datasets were rated highly on an overall basis, with data completeness (comprehensive) and quality being identified as major issues. The report recommended the need for:

1. Effective linkages between those that generate the data and those that hold the data (custodians),
2. Improvement of the datasets for integrated use (filling data gaps; metadata documentation; base mapping and scales, particularly for shorelines; comparing different datasets which use point, line and/or polygon data; updating; addressing “vintage” data; data accessibility), and
3. Identifying and addressing data requirements for emerging issues (climate change, ecosystem management).

The report also identified a list of potential core themes for ocean strategy business shown in Table 7.1 based on input from the associated project workshop. The core environmental themes have been considered in the review of potential marine attributes for BC Hydro.

Table 7-1: List of Core Themes for Ocean Strategy Business Use[c]

Marine Mammals
Marine-associated Birds
Shorezone
Marine Plants (kelp, eelgrass, salt marshes
Intertidal Bivalves
Estuaries
Salmon and Eulachon Rivers
Herring Spawning
Sponge Reefs
Rare and Endangered Species
Invasive Species
High Current Areas and Persistent Shears, Fronts and Upwellings
Benthic Habitats
Offshore Habitats
Commercial Fisheries
Recreational Fisheries
First Nation Resource Use
First Nation Traditional Territories
Aquaculture
Parks and Protected Areas
Tourism and Recreation
Archeological Sites
Culture and Heritage Resources
Coastal Plans and Other Land Use Plans
Military Exercise Areas
Navigation Routes
Ocean Dumpsites and Marine Waste Discharges
Shellfish Closures
Oil and Gas Potential

7.2.2 Review of Valued Marine Features

Lemieux et al. (2007) address a listing of valued marine features required to define areas of significance in the marine environment. The report provided an overview of initiatives in Canada, the United States and European Union to identify areas of significance, including the types of valued marine features used to identify these areas. For British Columbia the review draws largely from work on valued marine ecosystem features (VMEFs) by Norman Dale (Dale, 1997). The listed valued marine ecosystem features determined by this review process are shown in Appendix B. These ecosystem features have been considered in the review of potential marine attributes for BC Hydro.

[c] Wainright et al. 2007

7.2.3 GeoBC

GeoBC is the main BC data repository where spatial marine resource data are available publicly (www.geobc.gov.bc.ca). Both provincial and federal datasets are compiled (e.g., bird colony locations, herring spawn areas) as well as biophysical inventory and classification (e.g., ShoreZone and BC's Marine Ecoregions). Compilation data atlases for regional planning processes are also presented (e.g., for the north and central coast LRMPs). Some datasets are available for download from the publicly accessible site, while others are represented only in mapped atlas views.

7.2.4 BC Marine Conservation Area Strategy

The BC Marine Conservation Area Strategy (BCMCA) is compiling coast-wide resource datasets for use in MARXAN modelling to identify key areas of significance and assist with conservation planning (www.bcmca.net). A number of selected themes will be mapped in an atlas presentation, although the main objective is to develop the geospatial model for identifying key areas of significance. Themes include marine mammals and birds, marine plants, and human use. BCMCA is working closely with the Province to provide updates for the GeoBC online datasets (Carol Ogborne, pers. comm.) Members of BCMCA include First Nations and NGOs as well as provincial and federal government agencies.

7.2.5 Pacific North Coast Integrated Management Area

The Pacific North Coast Integrated Management Area (PNCIMA) process was initiated by the federal government in 2004, and is now operating under a Memorandum of Understanding signed by Fisheries and Oceans Canada, Coastal First Nations, and the North Coast-Skeena First Nations Stewardship Society, in an area extending from the BC-Alaska border to Campbell River (www.pncima.org). The MOU document confirmed the commitment of all three parties to integrated marine use planning in the PNCIMA region to achieve the shared goals of maintaining healthy ocean ecosystems and sustaining local marine economies. Working closely with First Nations, marine spatial datasets are being compiled for the north coast region, however those efforts are intended to compliment, not duplicate, any work going on in other regional plans. Modeling spatial data is not part of the PNCIMA mandate.

7.2.6 Selection of Marine Attributes

The selection of the marine attributes follows the concepts used for the categories of terrestrial environmental attributes: land cover (productivity), landscape context (remoteness) and ecological features (habitat/species).

In terrestrial environments net primary productivity (NPP) has been used as a measure of ecosystem productivity. In the marine environment an "ecosystem productivity" category is complex as, ideally, it would reflect the multi-dimensional nature of the environment (water surface, water column and sea bed).

In addition the rationale for a remoteness category – the assumption that increasing ecological values are, in part, a function of increasing remoteness – does not hold for the marine environment. For example the Fraser River estuary and delta are, arguably, one of the most productive marine areas of the BC coast and yet are located adjacent to the largest urban area in the province. For these reasons the selection of marine attributes focused largely on valued ecological features, but an effort was also made to capture very general attributes of marine productivity through use of the bathymetry attribute for the ecosystem productivity category.

The core marine themes listed in Table 7.1 above, as well as the additional data and data sources summarized in Appendix B, were scanned for potential attributes, using the selection criteria outlined in Section 3.0, and a summary of the scanned attributes is provided in Appendix A. A summary of marine spatial datasets for British Columbia is presented in Appendix B.

7.3 MARINE ATTRIBUTES

7.3.1 Bathymetry

The composition and productivity of benthic (seabed) communities is highly influenced by water depth, which governs the degree of light penetration and, to a great degree, water salinity and temperature. Intertidal communities are subject to daily cycles of tidal inundation and the biotic community needs to be resistant to cycles of drying as well as exposure to wave energy. The shallow sub tidal “photic” zone (0-20 m) supports benthic plant growth, including the larger canopy kelps (bull kelp and giant kelp). At moderate depths (20-200 m) primary producers (plants) are rare but bottom areas tend to have reasonable water exchange due to wave action and tidal currents. At deeper depths, deposition-feeding communities dominate the seabed.

As such water depth (bathymetry) can serve as a measure of seabed communities and productivity in the similar way that “NPP” does in the terrestrial environment. The bathymetry attribute would be strengthened by incorporating data on seabed substrate (e.g., bedrock, sand, mud). Unfortunately comprehensive, reliable data on seabed substrate is not yet available for BC coastal environments, particularly for the highly diverse and productive near shore environment.

For this attribute the Canadian Hydrographic Service (CHS) 500 m gridded digital bathymetry model data was used. This data set provides coast wide depth based on a 500 x 500 m grid cell. For the attribute, the same depth zones as the BC ecological classification system (http://www.ilmb.gov.bc.ca/risc/pubs/coastal/marine/index.htm#marineecoclass.methods) were used, namely 1). Photic Zone -0-20m; 2). Shallow Zone – 20-200m; 3). Deep Zone - 200 -1000m; and 4) Abyssal Zone - >1000m.).

Ideally the intertidal zone (0 m to the higher high water mark) would be included as a separate bathymetric layer. However it was determined that the 500 m gridded dataset was not of sufficient resolution to reliably distinguish the intertidal zone. CHS is currently producing intertidal (foreshore) shape files for the BC coast and have completed Vancouver Island, the southern Gulf Islands and lower mainland areas (T. Curran, CHS, pers. comm.). It is recommended that the intertidal layer be added to the bathymetric attribute for future IRPs when coast wide data is available.

7.3.2 Valued Ecological Features

Both Dale et al. (1996) and Lemieux et al. (2007) list valued marine features required to define areas of significance in the marine environment (Appendix B). These valued ecological features are usually identified as valued ecosystem components (VECs) in marine environmental assessment processes. Appendix B lists valued marine features which were considered for inclusion as marine attributes. Spatial datasets for nine of these features met the selection criteria for marine environmental attributes including 1) Protected Areas (including Ecological Reserves); 2) Rockfish Conservation Areas (RCAs), 3) Coastal Estuaries; 4) Salt Marsh Areas; 5) Eelgrass Areas; 6) Canopy Kelp Beds; 7) Sponge Reef Areas; 8) Important Bird Areas; 9) Herring Spawning Areas.

The Valued Ecological Features attribute is reported as hectares of valued features within each of the following categories 1) No Valued Ecological Features 2) 1-2 Valued Ecological Features; 3) 3-5 Valued Ecological Features 4) >5 Valued Ecological Features. These valued ecological features are reviewed below.

7.3.2.1 Marine Protected Areas, Ecological Reserves and Rockfish Conservation Areas

There are several classes of protected areas within the marine environment (http://www.env.gov.bc.ca/omfd/ocean-resources/mpa.html). The highest degree of protection/ conservation is afforded by BC Ecological Reserve status, where most human activities, including access, are under some level of restriction. There are 20 ecological reserves with a marine component. BC has more than 128 provincially or federally designated marine protected areas (MPAs). Most MPAs were established historically as marine recreational areas (anchorages, camping areas) with limited conservation mandate or rationale. More recently MPAs have been established with a conservation mandate (Race Rocks and, most recently, the Gwaii Haanas Marine Conservation Area.

Fisheries and Oceans Canada has established a network of over 100 rockfish conservation areas (RCAs) in British Columbia (http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/rca-acs/index-eng.htm). All commercial and recreational fishing by any means which might result in rockfish capture are not permitted in RCAs. Energy generation activities are not specifically prohibited within an RCA, however it should be assumed that DFO may request that such activities (including submarine transmission cables) avoid RCAs when possible.

Geospatial data defining ecological reserves and marine protected areas are available through GeoBC. Data on RCAs is available from Fisheries and Oceans Canada.

7.3.2.2 Coastal Estuaries

The Canadian Wildlife Service (CWS) has mapped 442 major coastal estuaries in British Columbia, rating their relative values based on: estuary size, habitat type and rarity, herring spawn occurrence, waterbird use, and intertidal biodiversity (Kenyon et al. 2007). The digital data is available for the CWS upon request (Kathleen Moore, CWS, per. comm.). In addition the ShoreZone classification (see below) includes an estuary type shore unit. While there is considerable overlap between the two datasets, the ShoreZone classification indentifies many smaller coastal estuaries which are not included in the CWS mapping.

To map coastal estuaries for marine environmental attribute purposes, the two data sets were combined into a single "coastal estuary" measure. If both datasets identified a coastal estuary at a specific area, the CWS data was used to plot the estuary area, as the CWS data is more spatially precise than ShoreZone.

7.3.2.3 Salt Marsh, Eelgrass, Canopy Kelps

Since the early 1980's British Columbia has carried out low tide aerial video surveys of the BC coast. The video data was systematically classified for physical and biological attributes such as shore type, habitat type, and biological features (presence and abundance of salt marsh, kelps and eelgrass) (ftp://ftp.gis.luco.gov.bc.ca/pub/coastal/rpts/BCBiophysicalShore-ZoneMapping.pdf). The surveying and mapping of the BC coast (over 30,000 km) was completed in 2002. The building block of the classification system is the shore unit, a length of shoreline with similar physical characteristics. There are 32 designated shore unit types which vary in length from 100s of metres to several kilometres. The spatial data set is linear (lines not polygons). Biological attributes (salt marsh, eelgrass, canopy kelps) are associated with each shore unit as a per cent of shore unit length (e.g., eelgrass is present on 50% of the shore unit). For use as environmental measures, the linear shore unit was converted to polygon data by buffering 50 m on either side of the shore line, and the valued ecological feature (e.g., eelgrass) was considered to occur over the whole length of the shore unit regardless to the "per cent of shore length" information in the Shore Zone database. The following caveats apply to use of this information as a marine environmental attribute:

- The coastal survey information is at least ten years old and some areas of the Strait of Georgia were surveyed over 25 years ago,
- Biological attributes such as eelgrass were not classified for some areas of the Strait of Georgia, and

- The spatial data set does not provide precise positioning of these biological features; they are identified as being present within the shore unit.

Shore Zone mapping and associated data are available through GeoBC.

7.3.2.4 Herring Spawning Areas

Records of herring spawning events (location, extent and intensity) have been collected since 1928, generating one of the most extensive biological, location-based datasets for the BC coast (30,000 spawning events at 1,379 locations - http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/project-eng.htm#2. Fisheries and Oceans Canada classifies documented herring spawning areas into six categories (vital, major, high, medium, low, minor). The initial spatial information was assembled as linear data (kilometres of shoreline) but more recently, as polygons. Herring spawning area spatial data is available from both Fisheries and Oceans Canada and GeoBC.

7.3.2.5 Sponge Reefs

Reef forming glass sponges are found in the Queen Charlotte Basin and the Strait of Georgia. First discovered in 1987, these sponge reefs are thought to be over 9,000 years old. They grow at depths up to 200 m and can reach a height of 25 m. Their value as a deeper water habitat feature is just beginning to be understood. Recently (June, 2010) the major sponge reefs in the Strait of Georgia have been declared an “Area of Interest” for future MPA designation by the Federal Government.

Spatial data for sponge reef locations in the Queen Charlotte Basin and the Strait of Georgia are available for Fisheries and Oceans Canada (http://www.pac.dfo-mpo.gc.ca/gis-sig/themes-eng.htm).

7.3.2.6 Important Bird Areas

From 1997 to 2001 Bird Studies Canada identified Important Bird Areas (IBAs) in Canada using selection criteria consistent with international IBA programs, including threatened species, restricted range species, biome restricted species and areas of important for species aggregation (congregatory species). A total of 68 IBAs were indentified for coastal British Columbia (both upland and marine habitats). As such IBAs were selected to represent valued ecological feature for marine birds (Appendix A). Shape files for coastal IBAs were obtained through IBA Canada (http://www.ibacanada.com/contact.jsp?lang=en).

7.3.3 Commercial Bottom Fisheries Areas

Fisheries and Oceans Canada provides geospatial data on commercial fishing effort and catch. The data is summarized as effort (categories of effort such as soak time, number of vessels, fishing sets) or catch within 4 by 4 km grid units. This data is available from Fisheries and Oceans, either by request or from

DFO's Mapster website. More recently this data is also available through the GeoBC portal. Currently the data available through DFO covers the period from 1996-2004. There are a number of important caveats about use of this data:

- This information is derived from a variety of sources ranging from fishing logbooks (least reliable) to GPS based electronic fishing activity monitoring systems (most reliable),
- To meet confidentiality requirements, these data are reported only if more than three fishing vessels report catch from the same grid cell. Therefore areas with a small amount of fishing activity are unreported,
- Catch and effort are influenced by fisheries management decisions (i.e., area closures, changes to quotas, shift towards individual quota fisheries) which may change significantly over time. The 1996-2004 time period does not reflect some recent developments such as the move to integrated groundfish management in British Columbia in 2006, and
- The 1996-2004 dataset does not include catch or effort information for the BC halibut longline fishery which is managed by the International Pacific Halibut Commission (IPHC). IPHC reports catch and effort data by IPHC fishing areas, which are large and unsuitable for attribute use.

Seabed areas where benthic species are commercially fished are generally indicative of areas of aggregation for these species. These areas may represent spawning areas, important seasonal feeding or holding areas or important migratory corridors. In addition benthic species are usually harvested with fixed gear (long line or traps) or mobile bottom trawl gear that present the highest risk of interaction with offshore power generation. Pelagic species (salmon, herring) are considered too mobile for fishing areas to serve as a general measure of important fish habitat.

For these reasons the commercial fishing attribute focuses on benthic target species harvested with fixed gear or mobile trawl gear, namely 1) crab by trap; 2) prawns by trap; 3) sablefish by trap; 4) shrimp by trawl; 5) groundfish by trawl and; 6) groundfish by hook and line (mostly bottom long line gear). Data sources and attribute classification are summarized in Table 7.2. The attribute classification does not account for the relative differences in commercial catch or effort within the gridded cells; if catch for one of the selected fisheries is reported within the grid cell it is recorded as a key commercial bottom fishing area. Ideally the attribute data set should be updated with current catch and effort data when it becomes available.

7.3.4 Summary Table

The rationale for the selection, the data sources and the classes are summarized for the three marine environmental attributes in Table 7.2. A review of all the potential attributes considered is provided in Appendix A.

Table 7-2: Summary of Marine Attributes, Including Rationale, Data Sources and Classification Categories

Attribute	Description	Rationale	Data Sources	Measure & Classifications
Bathymetry	Water depth classes	These depth classes influence seabed community composition and productivity	Canadian Hydrographic Service (CHS) 500 m gridded digital bathymetry model data	Hectares (ha) within each of the following zones: 1. Photic Zone 0-20 m 2. Shallow Zone >20-200 m 3. Deep Zone >200-1000 m 4. Abyssal Zone >1000 m
Valued Ecological Features	A group of nine marine habitats of acknowledged high ecological value: 1. Protected Areas 2. Rockfish Conservation Areas 3. Coastal Estuaries 4. Salt Marsh Areas 5. Eelgrass Areas 6. Canopy Kelp Beds 7. Sponge Reef Areas 8. Important Bird Areas 9. Herring Spawning Areas	These habitats are usually identified as valued ecosystem components (VECs) in marine environmental assessment processes	**GeoBC (ILMB)** www.geobc.gov.bc.ca *ShoreZone Data* • Eelgrass • Canopy kelps • Salt marsh • Coastal estuaries Marine Protected Areas Ecological Reserves Herring Spawning Areas http://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=3855&recordSet=ISO19115 **DFO** Rockfish Conservation Areas http://www.pac.dfo-mpo.gc.ca/gis-sig/themes-eng.htm Sponge Reef Areas http://www.canbcdw.pac.dfo-mpo.gc.ca/ows/imf.jsp?site=mapster **Canadian Wildlife Service** Known Estuaries of BC (Kenyon et al. 2007) **Bird Studies Canada** Important Bird Areas http://www.ibacanada.com/contact.jsp?lang=en	Hectares (ha) within each of the following classes: No Valued Ecological Features 1 Valued Ecological Features 2-3 Valued Ecological Features >3 Valued Ecological Features

Attribute	Description	Rationale	Data Sources	Measure & Classifications
Key Commercial Bottom Fishing Areas	Seabed areas where benthic species harvested with fixed gear (longline or traps) as well as benthic trawl gear including • Crab (trap) • Prawns (trap) • Sablefish (trap) • Shrimp Trawl • Groundfish (trawl) • Groundfish (hook and line) Commercial catch and effort for these fisheries are mapped as 4 x 4 km gridded areas of relative catch and effort	Fixed gear (trap, longline) and trawl fishing areas are relatively static and reflect areas of concentration of the target species. These gear types also present the highest risk of fisheries interactions with offshore power generation.	DFO – Mapster website http://www.canbcdw.pac.dfo-mpo.gc.ca/ows/imf.jsp?site=mapster	Hectares with commercial catch in each of the following classes: Class 1. No Bottom Fisheries Class 2. 1 Bottom Fishery Class 3. 2-3 Bottom Fisheries Class 3. >3 Bottom Fisheries

8.0 AIR ATTRIBUTES

8.1 INTRODUCTION TO ATMOSPHERIC ATTRIBUTES FOR ELECTRICITY PRODUCTION

Electricity production generates atmospheric pollution with local, regional, and global implications.

This study quantifies the contribution of air pollutants from the range of electricity generation resource options evaluated by BC Hydro in the *2011 Integrated Resource Plan*. The study also quantifies the contribution of greenhouse gases responsible for human-induced climate change from these same resource options.

Electricity production generates air pollutants and greenhouse gases along a life cycle of activity, including the construction of the facility, clearing of land for roads and transmission lines, extraction and transportation of fuel necessary to operate the facility, the combustion of fuel during electricity generation, fugitive emissions at the facility, and emissions associated with the disposal of waste in some cases. This study focuses on the largest emission-related activity: direct emissions generated during the combustion of fuels for electricity generation.

The combustion of fossil fuels such as coal and natural gas, and biomass such as wood generates air pollutants that can impact local and regional human health, agriculture, flora and fauna in aquatic, marine and terrestrial ecosystems, and infrastructure through acid deposition. National regulations govern the maximum acceptable ambient levels of the most prevalent and harmful pollutants, while provincial and local laws set limits on the concentrations of pollutants by different industries – including electricity production. This study quantifies and individually reports on carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), sulphur oxides (SOx), volatile organic compounds (VOCs), and mercury (Hg).

Human induced climate change is attributed to the rising concentrations of greenhouse gases in the global atmosphere primarily from the combustion of fossil fuels for energy, and secondarily the clearing of forests for timber, fuel, agriculture and settlements, and in this case transmission lines, roads and plants. Relevant greenhouse gases from electricity production are, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and sulphur hexafluoride (SF_6). These heat-trapping gases are contributing to an incremental rise in global temperatures disrupting natural and physical systems upon which ecosystems and the health and prosperity of humanity depend.

The most recent International Panel on Climate Change (IPCC, 2007) report concluded global greenhouse gases must peak before 2015, with 50-85 per cent reductions below 2000 levels by 2050, if we are to avoid tipping points that will cause dangerous disruptions, such as severe agricultural collapses, water shortages, droughts and sea level rise. To prevent dangerous climate change, local,

provincial, national and international government bodies have set targets and established frameworks for reducing GHG emissions. The Province of British Columbia has a legislative target of 33% emission reductions over 2007 levels by 2020 and 80% by the year 2050. BC Hydro has a goal of offsetting all of the GHG emissions from thermal power generation by 2016.

8.2 ATTRIBUTE SELECTION

Individual attributes were selected based on their environmental relevance and the project criteria for attributes, notably the priority local, provincial and federal regulators place specifically on air pollutants as well as greenhouse gas emission management. These attributes, moreover, are consistent with the BC Hydro's *2005 Resource Options Report* with some data availability limitations.

8.2.1 Air Pollution

Carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), sulphur oxides (SOx), volatile organic compounds (VOCs), and mercury (Hg) were selected because they represent the air contaminants that are of the biggest concern to local air quality and human health, and which are emitted by the resource options under consideration. Total PM is reported for all applicable resource options and PM_{10} is reported where data was available at the time of the study.

8.2.1.1 Particulate Matter

Particulate matter is the most challenging air attribute for which to compile complete results because of the multiple categories and measurement methods. From a health perspective, particulate matter that is 2.5 microns in diameter and smaller ($PM_{2.5}$) is of the greatest concern because of its ability to penetrate to the gas exchange regions of the lungs, with smaller particles passing to other organs. Most $PM_{2.5}$ present in ambient air was emitted as a gas (NOx or SOx) or larger particle from a combustion process. The particulates that form from gases are called "condensable particulate matter," recognizing the transformation that they undergo. In urban environments condensable PM constitute as much as 60% of existing PM_{10}. Generally, "condensable PM" falls into the category of PM_{10}, with the majority of the particulates occurring as $PM_{2.5}$ or $PM_{1.0}$. When measuring particulate matter in the ambient air it is not necessary to distinguish condensable PM from other types, because typically this transformation happens relatively quickly after gases leave the stack and cool in the surrounding air. Measuring condensable PM becomes important when assessing the emission rate of an individual facility/engine, because at the outlet of the exhaust stack it will still be in the form of a gas. Thus, methods that capture PM that is "filterable" (solids and liquids) and condensable (gases) need to be used in order to accurately assess the amount that is present in the ambient air. Reports of particulate matter emission rates frequently do not specify which method was used, nor are definitions provided for the categories of PM. As an example,

when “total PM” is reported, it is rarely specified whether it includes both filterable and condensable PM, or filterable PM of all diameters.

Environment Canada defines total particulate matter as "any particulate matter with a diameter less than 100 microns." Environment Canada defines "condensable PM" as “gases/vapours that are emitted from facilities that subsequently condense to form particulate matter.”

In the BC regulatory context the following definitions apply: "total particulate matter" concentrations constitute filterable particulate matter as determined by EPA Method 5. “PM_{10}" and “$PM_{2.5}$" include filterable and condensable particulate matter as determined by US EPA test methods 5 and 202.

While populating the PM attribute values for this study it was discovered that in several cases “filterable PM” was classified as PM_{10} in the *2005 BC Hydro Resource Options Report*. The data sources referenced for the natural gas PM_{10} emission factors in the 2005 report appear to be based on EPA Method 5 which captures filterable particulates of all sizes.

The data sources utilised for the municipal solid waste-to-energy resource options report PM in terms of "total PM," but do not clarify if this is only filterable, or both filterable and condensable PM.

As a result of these findings, "total PM" was added to the list of attributes, and includes the reclassified PM_{10} values from the *2005 Resource Options Report*. It should be clarified that "total PM" refers to total filterable PM of sizes less than 100 microns; it is not the sum of "filterable" and "condensable" PM, as the term "total PM" is sometimes used in the literature. For the purpose of this study, “total PM” does not include “condensable PM.” Given the high-level evaluation at this stage in electricity planning, “total PM” is the attribute used for measuring relative particulate matter emissions for different resource options.

8.2.2 Greenhouse Gas Emissions

The preeminent scientific authority, the Intergovernmental Panel on Climate Change recognizes six gases generated from human activity as greenhouse gases. These gases are covered under the UN Framework Convention on Climate Change as well as legislation establishing reduction targets in BC. For this study the relevant greenhouse gases were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and sulphur hexafluoride (SF_6). Greenhouse gases are reported as carbon dioxide equivalent (CO_2e) representing the weighted global warming potential of each gas relative to carbon dioxide. Calculations were based on methodologies consistent with the Climate Registry, the UN Framework Convention on Climate Change as well as the Canadian Government.

Carbon from biomass such as wood combusted for power and actively cycling in the biosphere, i.e., replaced through reforestation, is treated differently for greenhouse gas accounting purposes than fossil

carbon that is reintroduced to the biosphere after being inactive over geologic timescales. The active or "biogenic" carbon is considered "carbon neutral," or having an emissions factor of zero. Resource options that produce carbon neutral emissions include wood-derived biomass and landfill gas.

8.3 STUDY SCOPE

The study necessitated focus largely due to the relevance, (i.e., magnitude), of emissions across the life cycle of electricity production and data availability. These limitations are explained below.

8.3.1 Emissions versus Impacts Approach

In contrast to the marine, fresh water and land attributes, atmospheric attributes selected are stressors rather than potential impacts. Data constraints do not permit a cost-effective, comprehensive comparison of air pollution impacts on human health, nor agriculture and ecosystems. Most fundamentally, there is not a comprehensive comparison of air pollutants across BC to which marginal increases from future power generation could be added on a regional level to consider future human health impacts.

In regards to climate change, local greenhouse gas emissions are far removed from their impacts which spatially are global, and temporally will endure for generations. Attributing specific impacts exclusively to climate change is, moreover, difficult and controversial. While there are many studies forecasting the cost per tonne of carbon (dioxide), prices typically reflect emission reduction policy objectives not climate change impacts. There are some notable exceptions. Nevertheless such reputable studies provide a wide margin of error and include significant caveats (see European Commission, 2003).[4]

The best comprehensive comparison in the BC context, therefore, is using stressors (i.e., air pollutants and greenhouse gas emissions) that lead to impacts. That is this study's approach.

8.3.2 Treatment of Direct Emissions and Power Plant Operation

In addition to direct power plant combustion emissions, electricity production generates small but significant greenhouse gases during other phases of activity such as construction or processing and transport of fuels – see Figure 8.1 below. These emissions are generally 1) small in comparison to emissions from fuel combustion at a power plant and 2) very difficult to quantify because of lack of a comprehensive and consistent data across all resource options for comparative analysis. Greenhouse gas analysis in this study focuses on direct emissions during power plant operation, i.e., fuel combustion.

BC Hydro, additionally, commissioned a more comprehensive study on GHG emissions for Site C, which will feed into the environmental assessment process. This study, notably, projects the still relatively small

[4] This study evaluates air pollution and GHG impacts according to cost: European Commission, 2003. *External Costs: Research Results on Socio-Environmental Damages due to Electricity and Transport.*

but significant amount of greenhouse gases that would be emitted from the reservoir (Jacques Whitford AXYS, 2009).[5]

[5] Jacques Whitford AXYS, 2009. *Peace River Site C Hydro Project: Baseline Greenhouse Gas Emissions Report.* Available at http://www.bchydro.com/planning_regulatory/site_c/document_centre/Environment_Socio_economic_reports.html

Figure 8-1: Electricity Production GHG Life Cycle Matrix[6]

	Construction					Operation					End-of-Life
	Upstream (Offsite)			Direct (Onsite)		Upstream (Offsite)		Direct (Onsite)			Onsite & Offsite
Resource Options	Construction Material-Inputs Manufacturing	Energy Feedstock Production (extraction & processing)	Transport	Combustion (Construction Equipment, Vehicles & Buildings)	Land Use (Forestry & Reservoir Emissions)	O&M Material-Inputs Manufacturing	Energy Feedstock Production (extraction & processing)	Transport	Combustion[7]	Plant Fugitive Emissions	Fuel Waste Management, Disposal & Plant Decommissioning
Fossil Fuel Thermal Plant	○	○	○	○	○	◎	◎	○	•	○	○
Biomass Thermal	○	○	○	○	○			○	○	○	○
Waste-to-Energy	○	○	○	○	○	◎	◎	○	•	○	○
Small Hydro	○	○	○	○	○						○
Large Hydro[8]	○	○	○	○	◎						○
Geothermal	○	○	○	○	○					○	○
Wind	○	○	○	○	○	◎					○
Solar	○	○	○	○	○	◎					○

Key

Focus of analysis for this study	•	240 – 700 Tonnes CO_2e / GWh	◎	10 – 100 Tonnes CO_2e / GWh	○	< 10 Tonnes CO_2e / GWh		Zero Tonnes CO_2e / GWh

[6] The matrix shows phases over the life cycle of power production and the relative GHG intensity per GWh organized by resource option
[7] The Summary Table of emissions on page 10 includes only emissions from combustion.
[8] Reservoir emissions from Site C have been calculated in a separate study.

8.3.3 Airshed Vulnerability Analysis Limitations

Threshold levels are important, particularly for some air pollutants, above which there are demonstrated health effects, and below which there are not. There is no comprehensive province-wide assessment and comparison of airshed quality, and evaluating vulnerability from incremental additions to air pollution would require dispersion modeling which is a substantial effort for this high level planning stage of an Integrated Resource Plan. It is for these reasons, that air pollutant attributes reflect values for specific resource options rather than their cumulative impact on airshed vulnerability.

8.4 METHODOLOGY OVERVIEW

The following overview explains the essential steps involved in calculating greenhouse gas and air pollution attribute values.

8.4.1 Direct Power Plant Combustion Emissions

The following steps were followed to identify the appropriate values for the air and greenhouse gas attributes:

- BC Hydro indentified the resource options to be included in the Integrated Resource Plan, including the technical specifications of the facilities, fuels, and the emission control technologies.
- Consultants reviewed the 2005 Resource Options Report to identify equivalent resource options.
  - Consult *Appendix B: Project and Program Database*, to identify resource options and technology specifications that have not changed; utilize attribute values for those resources.
- Consult the following references to identify attribute values for those resource/technology options that differ from the 2005 Resource Options Report:
  - Air pollution from direct operational combustion, primary references:
    - United States EPA, AP-42
    - For MSW WTE facilities:
      - AECOM 2009. *Management of Municipal Solid Waste in Metro Vancouver – A comparative analysis of options for management of waste after recycling.*
      - Stantec 2010. *Waste to Energy – A technical review of municipal solid waste thermal treatment practices*. Prepared for Environmental Quality Branch, BC Ministry of Environment.
    - Please see Table 8.1 for a more comprehensive list of data sources.
  - GHGs from direct operational combustion, primary references:
    - The Climate Registry,
    - Natural Resources Canada, and
    - Please see Table 8-2 for a more comprehensive list of data sources.

A comprehensive delineation of air pollution and GHG values, assumptions and sources is found in Tables 8-1 and 8.2, below.

8.5 SUMMARY TABLES

Table 8-1: Direct Plant Combustion Air and GHG Values by Resource

Resource Option		GHGs[9,10]	Air Emissions[9,11,12]					
		CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
1	Biomass : Wood-based	0	0.36	0.039	0.026	0.54	0.36	-
2	Landfill Gas - Reciprocating ICE	0	1.67	0.108	4.86	4.46	0.015	-
3	MSW - Unsorted Incineration	694	0.97	0.24	0.012	0.16	0.024	0.000016
4	Wind	0	0	0	0	0	0	0
5	Geothermal	0	0	0	0	0	0	0
6	Small Hydro	0	0	0	0	0	0	0
7	Pumped Storage	0	0	0	0	0	0	0
8	Large Hydro (Site C)	0	0	0	0	0	0	0
9	Resource Smart	0	0	0	0	0	0	0
10	Natural Gas - 100 MW Single Cycle Gas Turbine (Vancouver Island)	477	0.08	0	-	1.4	0.03	-
11	Natural Gas - 100 MW Single Cycle Gas Turbine (Kelly Lake)	477	0.37	0	-	1.4	0.03	-
12	Natural Gas - 50 MW Combined Cycle Gas Turbine	390	0.04	0.003	-	0.18	0.02	-
13	Natural Gas - 250 MW Combined Cycle Gas Turbine	365	0.05	0.004	-	0.06	0.03	-
14	Natural Gas - 500 MW Combined Cycle Gas Turbine	365	0.05	0.004	-	0.06	0.03	-
15	Natural Gas - Small Cogeneration from Independent Power Producers	240	0.25	0.0047	-	0.058	0.0037	-
16	Coal - 750 MW Integrated Gasification Combined Cycle with 90% Carbon Capture and Storage	93	0.2224	0.0456	N/A	N/A	0.0335	0.0000026799
17	Ocean	0	0	0	0	0	0	0
18	Hydrokinetic	0	0	0	0	0	0	0
19	Energy Storage	0	0	0	0	0	0	0
20	Solar	0	0	0	0	0	0	0
21	Nuclear	0	0	0	0	0	0	0

[9] Measured in Tonnes/GWh.
[10] GHGs are expressed as CO2e according to accepted IPCC methodologies and include CO2, CH4, N2O, and SF6.
[11] N/A indicates "not measured" in the data sources used.
[12] - indicates negligible value.

Table 8-2: Direct Plant Combustion Air & GHG Values, Assumptions & Sources by Resource

1. Biomass (Wood-based)	GHGs[9,10]	Air Emissions[9,11,12]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0.36	0.039	0.026	0.54	0.36	-

Assumptions & Notes:
- PM10 performance is 0.18 Tonnes/GWh
- Mass-burn, no cogeneration
- 35 MW average plant size
- 91% capacity factor
- 2.45 m^3 of wood = 1 oven dry tonne (ODT)
- 1 MWh electricity requires 0.72 ODT
- Clean (non-treated) wood
- Pollution Control Technologies:
  - Electrostatic precipitators used for PM control
  - Two-stage combustion used to control NOx

Data Sources:
- Envirochem 2008. Emissions from Wood-Fired Combustion Equipment. Prepared for BC Ministry of the Environment.

Notes:
- All units expressed as Tonnes/GWh
- GHGs are expressed as CO_2e according to accepted UN Framework Convention and Climate Registry methodologies and include CO_2, CH_4, N_{2O}, and SF_6
- Tables represent emissions from direct plant combustion only.

2. Biomass (Biogas)	GHGs[9,10]	Air Emissions[9,11,12]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
Landfill Gas – Reciprocating ICE	0	1.67	0.108	4.86	4.46	0.015	-

Assumptions & Notes:
- Biogas composition: 50% methane, 50% CO_2, <1% other gases
- No cogeneration
- 800kW - 3 MW in size
- 90% capacity factor
- Heat rate = 11.53 BTU/MW
- No post combustion pollution control devices used. CO and NOx are controlled through combustion adjustments.

Data Sources:
- Technology Specifications:
  - BC MOE 2010. *Landfill Gas Management Design Guidelines*. Prepared by Conestoga-Rovers & Associates.
- Air Emission Factors:
  - US EPA 2008. *AP-42*, Section 2, Chapter 4, Draft.
  - Envirochem 2009. *Review of the Hartland Landfill Gas Monitoring Program*. Prepared for the Capital Regional District.[13]

[13] The Hartland Landfill power generation project fits the specifications for BC Hydro's "typical facility" and therefore actual monitoring data from the engine was used for the purpose of identifying the indicator values.

3. Biomass (MSW)	GHGs[9,10]	Air Emissions[9]					
	CO2e	NOx	SOx	VOCs	CO	PM Total	Hg
Unsorted Incineration	694	0.97	0.24	0.012	0.16	0.024	0.000016

Assumptions & Notes:

- The MSW is assumed to be unsorted (although upstream waste-diversion, such as compost or recycling, is assumed)
- The waste composition is assumed to be similar to that reported by Metro Vancouver
- No Cogeneration
- Facilities range in size between 12 and 34 MW
- No assumptions for heat rates were made. A general conversion factor of 0.6 MWh per tonne of MSW was assumed in calculating the energy output.
- Air emission factors are based on upper estimate of emission rate associated with the selected control technologies in Stantec (2010), chapter 4: NOx: 120 mg/m^3, SOx: 30 mg/m^3, Total PM: 3 mg/m^3, CO: 20 mg/m^3, Hg: 0.002 mg/m^3, VOCs 10 mg / m^3. All of these rates fall within the recommended regulatory limits that are put forward in the report.
- GHG emission factor based on AECOM (2009), using data from the Metro Vancouver WTE facility 2007 calculation: 1.157 tonnes CO_2e per tonne of MSW (p 126). 36% carbon is assumed to be fossil, 64% is assumed to be organic. Only the fossil carbon is included in the CO_2e emission factor.
- Exhaust gas flow rate of 66.9kg/s for a facility processing 120,000 t of solid waste per year, based on Qiu *et al*. (2005).
- Emission Control Technology:
  - Powdered activated carbon injection (removal of trace VOCs and mercury)
  - Electrostatic precipitators (removal of PM 2.5 and PM 10)
  - Dry/semi-dry scrubber (removal of SOx, HCl and HF)
  - Ammonia injection system (reduction of NOx)

Data Sources:

- Technical Specifications and Air Emission Factors:
  - Stantec 2010. *Waste to Energy: A technical review of municipal solid waste thermal treatment practices*. Prepared for BC Ministry of the Environment.
- GHG Emission Factors:
  - AECOM Canada Ltd. 2009. *Management of Municipal Solid Waste in Metro Vancouver – A Comparative Analysis of Options for Management of Waste After Recycling.*
- Exhaust Gas Flow Rate:
  - Qiu *et al.* 2005. *Integrated energy from waste systems -- MSW and natural gas combined cycles for high-efficiency power production.* Canmet Energy Technology Centre, Natural Resources Canada.

4. Wind (Onshore and Offshore)	GHGs[9,10]	Air Emissions[9]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0	0	0	0	0	0

Assumptions & Notes:

- No direct emissions.

Data Sources:

5. Geo-thermal	GHGs[9,10]	Air Emissions[9]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0	0	0	0	0	0

Assumptions & Notes:

- No direct emissions.

Data Sources:

6. Hydro (Run-of-River)	GHGs[9,10]	Air Emissions[9]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0	0	0	0	0	0

Assumptions & Notes:

- No direct emissions.

Data Sources:

7. Hydro (Pumped Storage)	GHGs[9,10]	Air Emissions[9]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0	0	0	0	0	0

Assumptions & Notes:

- No direct emissions.

Data Sources:

8. Large Hydro (Site C)	GHGs[9,10]	Air Emissions[9]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0	0	0	0	0	0

Assumptions & Notes:
- No direct emissions.

Data Sources:

9. Resource Smart	GHGs[9,10]	Air Emissions[9]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0	0	0	0	0	0

Assumptions & Notes:
- No direct emissions.

Data Sources:

10. Thermal (Natural Gas) 100 MW Single Cycle Gas Turbine (Vancouver Island)	GHGs[9,10]	Air Emissions[9,11,12]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	477	0.08	0	-	1.4	0.03	-

Assumptions & Notes:
- A GE LMS100PA unit has been used to characterize a peaking gas-fired unit in the Kelly Lake region and Duke Point on Vancouver Island.
- The units would be equipped with water injection for NOx control.
- The Vancouver Island unit will have additional NOx control in the form of SCR.

Data Sources:
- HA, CO2e, NOx, SOx, CO, PM10:
  - AMEC, 2008. AMEC Gas-fired Combustion Turbine Power Plant Costs and Performance Updates. Appendix F7, BC Hydro's 2008 LTAP.
  - Gas Turbine World. 2010 GTW Handbook.

11. Thermal (Natural Gas) 100 MW Single Cycle Gas Turbine (Kelly Lake)	GHGs[9,10]	Air Emissions[9,11,12]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	477	0.37	0	-	1.4	0.03	-

Assumptions & Notes:
- A GE LMS100PA unit has been used to characterize a peaking gas-fired unit in the Kelly Lake region and Duke Point on Vancouver Island.
- The units would be equipped with water injection for NOx control.

Data Sources:
- HA, CO2e, NOx, SOx, CO, PM10:
  - AMEC, 2008. AMEC Gas-fired Combustion Turbine Power Plant Costs and Performance Updates. Appendix F7, BC Hydro's 2008 LTAP.
  - Gas Turbine World. 2010 GTW Handbook.

12. Thermal (Natural Gas) 50 MW Combined Cycle Gas Turbine	GHGs[9,10]	Air Emissions[9,11,12]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	390	0.04	0.003	-	0.18	0.02	-

Assumptions & Notes:
- A GE LM6000PD, operating at 70% capacity factor.
- Dry low NOx technology unit.
- SCR is also included for NOx reduction.
- The plant is assumed to shut down during the spring high run-off period.

Data Sources:
- HA, CO2e, NOx, SOx, CO, PM10:
  - AMEC, 2008. *AMEC Gas-fired Combustion Turbine Power Plant Costs and Performance Updates*. Appendix F7, BC Hydro's 2008 LTAP.

13. Thermal (Natural Gas)	GHGs[9,10]	Air Emissions[9,11,12]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
250 MW Combined Cycle Gas Turbine	365	0.05	0.004	-	0.06	0.03	-

Assumptions & Notes:
- A GE S207FA Combined Cycle unit
- Dry, low NOx unit with SCR NOx reduction

Data Sources:
- HA, CO2e, NOx, SOx, CO, PM10:
  - AMEC, 2008. *AMEC Gas-fired Combustion Turbine Power Plant Costs and Performance Updates*. Appendix F7, BC Hydro's 2008 LTAP.

14. Thermal (Natural Gas)	GHGs[9,10]	Air Emissions[9,11,12]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
500 MW Combined Cycle Gas Turbine	365	0.05	0.004	-	0.06	0.03	-

Assumptions & Notes:
- A GE S207FA Combined Cycle unit. Dry low NOx with SCR.

Data Sources:
- HA, CO2e, NOx, SOx, CO, PM10:
  - AMEC, 2008. *AMEC Gas-fired Combustion Turbine Power Plant Costs and Performance Updates.* Appendix F7, BC Hydro's 2008 LTAP.

15. Thermal (Natural Gas)	GHGs[9,10]	Air Emissions[9,11,12]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
Small Cogeneration from Independent Power Producers	240	0.25	0.0047	-	0.058	0.0037	-

Assumptions & Notes:
- Assumed that 1000 GWh would be taken up by IPO from the potential identified in the 2008 ROU.

Data Sources:
- HA, CO2e, NOx, Sox, CO, PM10:
  - BC Hydro 2008. *2008 Resource Options Update.*

16. Thermal (Coal with CCS)	GHGs[9,10]	Air Emissions[9,11]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
750 MW Integrated Gasification Combined Cycle with 90% Carbon Capture and Storage	93	0.2224	0.0456	N/A	N/A	0.0335	0.0000026799

Assumptions & Notes:
- See Data Source below, p. 131, for a full list of assumptions.

Data Sources:
- BC Hydro 2010. Data adapted from: National Energy Technology Laboratory 2007. *Cost and Performance Baseline for Fossil Energy Plants. Volume 1: Bituminous Coal and Natural Gas to Electricity: Final Report.* Case 2, Revision 1.

17. Ocean (Wave and Tidal)	GHGs[9,10]	Air Emissions[9]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0	0	0	0	0	0

Assumptions & Notes:
- No direct emissions.

Data Sources:

18. Solar	GHGs[9,10]	Air Emissions[9]					
	CO_2e	NO_x	SO_x	VOCs	CO	PM Total	Hg
	0	0	0	0	0	0	0

Assumptions & Notes:
- No direct emissions.

Data Sources:

9.0 APPLICATION OF THE ATTRIBUTES TO THE RESOURCE OPTIONS

This section outlines the procedure used to relate the environmental attribute and derive attribute values for the resource options.

The environmental attributes were populated for the potential resource options, by either:

- Intersecting the physical footprint with the environmental attribute maps for spatially based attributes (primarily Land, Freshwater and Marine), or
- Multiplying the emission rate (tonnes/GWh, dependant on the resource option and technology) by the generation (GWhr/year) for emissions based attributes (Air Contaminant & GHG Emissions).

9.1 SPATIALLY BASED ATTRIBUTES

The accuracy of the underlying physical and spatial data was considered when relating the resource option footprints and the environmental data, since:

- The resource options are spatially represented as point locations in a geographical information system (GIS) database (ROMAP),
- The potential resource option footprints, technical attributes and locations are, in most cases, conceptual and based on inventory level data (with exceptions such as Site C and Resource Smart), and
- The environmental attribute source data used to develop the GIS environmental attribute datasets also varies with respect to data completeness, confidence and spatial accuracy.

9.1.1 Probability Envelopes for Spatially Based Attributes

In recognition of the above, a buffer area in which the physical footprint of a potential resource option could be located was established. This was referred to as a 'probability envelope', which varied based on the resource option and its associated level of data confidence. The ROMAP database includes estimated footprints for the at-gate (generation site), road, and power line of each potential resource option. Figure 9-1 below provides a schematic diagram of this approach.

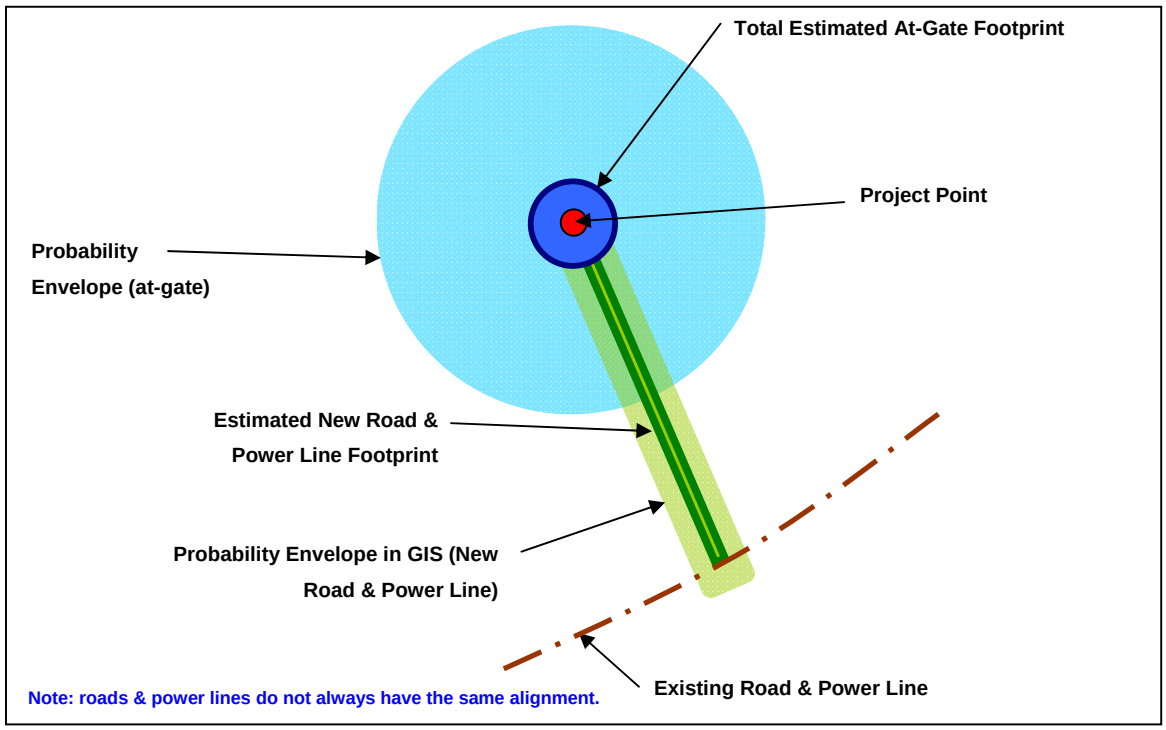

Figure 9-1: Schematic Diagram of Probability Envelope and Physical Footprints

Most of the probability envelopes were circles created by buffering a radius around the project generating location. The buffer radius for the probability envelope for each resource option is presented in Table 9-1 below:

Table 9-1: Resource Option At-Gate GIS Buffers for Probability Footprint Envelopes

Resource Type	Buffer Radius for Envelope (km)
Biomass (Biogas)	0.5
Biomass (MSW)	10
Biomass (Wood Based - Sawmill Wood Waste)	10
Biomass (Wood Based - Standing Timber)	50
Geothermal	50
Large Hydro (Site C)	0.1
Mica Pumped Storage	0.1
Pumped Storage	0.5
Resource Smart	N/A[14]
Run of River Hydro	0.5
Solar	10
Thermal (Natural Gas	10
Thermal (Coal with CCS)	50
Ocean Tidal	10
Ocean Wave	10
Wind (Onshore)	0.5
Wind (Off Shore)	10
Note: All resource option envelopes represented circles with a radius of buffer around the project footprint, with the exception of Site C, which used the project generation site polygon, and run-of-river hydro which used a straight line between the intake and power house	

[14] BC Hydro advised that there is negligible/no at-gate, road or power line footprint in addition to what is already there

The buffers used to develop the probability envelopes for the roads and power lines (both individual and clustered) for resource options as well as potential bulk roads and transmission are presented in Table 9-2 below:

Table 9-2: Road and Power Line GIS Buffers for Probability Footprint Envelopes

Line	Assumed Total Clearing Width (m)	Buffer on Either Side of Assumed Clearing Width (km)
Roads	10	0.5
Roads (Site C)	12	0.1
Power Lines - 25kV	15	0.5
Power Lines - 69kV	10	0.5
Power Lines - 138kV	30	0.5
Power Lines - 230kV (One or two lines)	38[a]	0.5
Power Lines - 500kV (One or two lines)	64[a]	0.5
Power Lines (Site C)	120	0.1

[a] For the new Potential Bulk (Cluster) Power Line segment between Campbell River to Dunsmuir, the additional new T3 environmental attribute footprint widths added to existing assumed clearing width was 28.5 m for 230 kV, and 48 m for 500 kV for one or two additional power line circuits

9.1.2 Application of Spatially Based Attributes

The physically based environmental attributes for the resource options were populated as follows:

- The resource option physical footprint probability envelopes were intersected in GIS with the environmental attribute datasets to produce probability envelope values for each attribute and resource option.
- Each attribute value was then weighted by the ratio of the estimated physical footprint to the probability envelope area to populate the environmental attributes for each resource option. This limited the total area for each attribute to less than or equal to the estimated footprint.

  This method resulted in a dataset of environmental attributes appropriate to the level of accuracy of this study.

9.1.2.1 Special Exceptions

There are a couple of notable exceptions to the above methodology where better information exists:

- All Resource Options (at-gate) (except run-of-river, large hydro and pumped storage).
  - o *Riparian Footprint:* assumed to be zero as a non-hydro project could be sited outside the riparian area.

- Run-of River at gate:
  - *Riparian Footprint:* estimated as 100% of the intake area, plus 30% of the estimated penstock area plus 100% of the powerhouse area.
  - *Affected Stream Length:* estimated as the penstock length.
- Large Hydro (Site C):
  - Reservoir area 9310 ha at normal operating level
  - *Affected Stream Length:* see table below.

Table 9-3: River Length Affected

River/Tributary	Length of River Inundated by Site C Reservoir (km)[a]
Peace River	83.0
Moberly River	10.0
Wilder Creek	2.5
Cache Creek	8.0
Red Creek	1.5
Halfway River	14.0
Farrell Creek	2.5
Lynx Creek	0.8
Maurice Creek	0.3
Total	**122.6**

[a] At maximum normal operating level

Resource Smart projects were assumed to have no additional environmental footprint that applied to the attributes developed in this project.

9.2 EMISSIONS BASED ATTRIBUTES - METHODOLOGY

The estimated emissions rates for air contaminants & GHG, specific to each resource option, were a function of the energy generated in a year. The product of the emission rate and annual energy generation was used to estimate the annual emissions in tonnes. Special exceptions were made for some resource options (such as Site C) where more detailed data was available.

10.0 SUMMARY

As a part of BC Hydro's 2011 Integrated Resource Plan (IRP) the environmental attributes used to characterize the energy generation resource options were updated

Environmental attribute measures were developed and updated to enable the characterization of the environmental attribute categories (Land, Freshwater, Marine and Air) for the resource options considered in the 2011 BC Hydro IRP. The attributes were developed to be applicable and appropriate at a provincial and inventory scale, be science based and defendable, as well as consider the BC Hydro energy generation portfolio analysis.

The attributes for air contaminant and greenhouse gas (GHG) emissions were largely unchanged since the previous BC Hydro studies.

The attributes by major attribute category (Land, Freshwater, Marine, and Air) are listed below:

- Land: Net Primary Productivity, Conservation Priority Species, and Linear Disturbance (remoteness),
- Freshwater: Riparian Footprint, Aquatic Footprint (reservoir area & affected stream length), and Priority Fish Species,
- Marine: Bathymetry, Valued Ecosystem Features, and Commercial Bottom Fisheries, and
- Air: Air Contaminants, and GHG Emissions.

Environmental attribute GIS datasets were developed for each spatially based attribute. These GIS datasets were intersected with the ROMAP resource option physical footprints using a probability envelope to account for data uncertainties.

Air contaminants and GHG emissions rates were estimated based on the resource option (and associated technology assumed) and annual emissions were estimated for each applicable resource option.

The project has resulted in a dataset of environmental attributes for all the potential resource options that can be summed across resource options in BC Hydro's portfolio analysis to help characterize the potential portfolios being considered by BC Hydro.

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Wainwright,P. B. Emmett. G. Lemieux and R. Bocking. 2007 Assessment of current information to support the Oceans Strategy. Prepared for the Integrated Land Management Bureau, BC Ministry of Agriculture and Lands and the Dept of Fisheries and Ocean by LGL Ltd, Sidney BC and Archipelago Marine Research Ltd. Victoria, BC.

APPENDIX A

Summary of Potential Attributes

Table 1: Potential Attributes

#	Attribute	Description/Measurement	Meets Criteria	Selected for Project	Comments/Rationale
Terrestrial					
L1	Ecosystem: Relative Net Primary Productivity (NPP)	Net Primary productivity (NPP) is a measurement of plant growth, based on the quantity of carbon absorbed and stored by vegetation.	Yes.	Yes	This is a quantitative measure that allows comparison between disparate systems. It meets criteria for inclusion as an attribute of the relative productivity of an area. It can be considered as a coarse-scale surrogate measure of biodiversity, with areas of higher primary productivity more likely to support a larger diversity of species.
L2	Disturbance: Linear Disturbance Density	Linear disturbance density is a measure of the degree of disturbance of an area (and its fragmentation) and its relative value to terrestrial wildlife, based on length of linear infrastructure per area of land. The measure includes linear infrastructure density categories (km of infrastructure per km^2).	Yes.	Yes	This is a quantitative measure that meets criteria for inclusion as an attribute. Linear density categories range from urban to remote and indicate relative habitat value to large terrestrial mammals. Large terrestrial mammals can be considered an 'umbrella' species, in the sense that remote areas that are more likely to support these species are also likely to support a suite of other species.
L3	Species: Conservation Framework High Priority Species Count Percentiles	Relative conservation value is a measure of the species conservation priority based MoE's Conservation Framework. High priority species were any species with a "Highest Priority"' of 1, 2, or 3. Percentile counts of species of elevated conservation concern (all species ranked in MoE's Conservation Framework). Could sum areas for ROs that fit within percentiles of counts of species ranked 1 to 3 per hectare under the MOE Conservation Framework.	Yes	Yes	This is a species measure that combines spatial distribution and conservation status. Species counts are arranged into percentiles to allow easy comparisons from one site to another. This measure meets all criteria for inclusion as an attribute.
L4	Land Cover	Basic thematic mapping	No	No	Basic thematic mapping was not included because it did not meet the criteria of being directly quantifiable for comparison across resource options. Further, land cover classifications reflect land use rather than an ecosystem characteristic.
L5	Land Conservation Score	Biodiversity BC applied Natureserve conservation status ranks to all Biogeoclimatic Ecosystem Classification (BEC) Zones in BC.	Yes	No	BEC zone status ranks were not included because information was deemed too coarse-scale to be meaningful for purposes of the Project.

#	Attribute	Description/Measurement	Meets Criteria	Selected for Project	Comments/Rationale
L6	Biodiversity Index	Land Conservancy of Canada developed a relative biodiversity index for some watersheds in central BC.	No	No	The biodiversity index measure was not included because it was not a province-wide data set and therefore did not meet criteria for inclusion.
L7	Ungulate Winter Range	Legally defined areas under the FRPA important for ungulates to meet life requisites through the winter.	No	No	UWRs were not included for the following reasons: • UWRs do not meet the criterion of being quantifiable or summable for comparison across resource options. • Management direction differs by UWR polygon. Some UWRs are more critical to wildlife survival than others, and these differences are too complex to convey in ROMAP. • Provincial coverage is not complete.
L8	Wildlife Habitat Areas	Legally defined areas under the FRPA critical for wildlife species to undergo life requisites including reproduction	No	No	WHAs were not included for the following reasons: • WHAs didn't meet the criteria of being quantifiable or summable for comparison across resource options. • Management direction differs by WHA polygon. Some WHAs are more critical to wildlife survival than others, and these differences are too complex to convey in ROMAP. • Provincial coverage is not complete
L9	Protected Areas	Parks and protected areas boundary outlines for all provincially protected areas.	No	No	Parks and protected areas were not included because resource options will not be located in parks and protected areas.
L10	Species at risk (SAR), Red or Blue	Known locations of red and blue listed species in the province collected and mapped by the BC Conservation Data Centre.	No	No	At risk species are captured under the species attribute Conservation Framework High Priority Species Count Percentile and were not included as a separate attribute. Dataset not representative in the sense that a lack of known location records does not necessarily indicate species absence from a given area.

#	Attribute	Description/Measurement	Meets Criteria	Selected for Project	Comments/Rationale
L11	Invasive Plant Score	Polygon area and geometry for an invasive plant site. Defined by the extent of a dominant invasive plant on a site if an inventory has been conducted. Where no inventory has been conducted the polygon may represent a site marker.	No	No	An invasive plant score was not included as an attribute because the dataset is not province-wide.
Freshwater					
F1	Species at Risk (provincial CDC) (SPECIES)	Species are assigned to the RED or BLUE list on the basis of the provincial Conservation Status Rank (SRANK) assigned by the Conservation Data Centre. Red = Endangered; Blue = Threatened	Yes	Yes	This has been rolled in with priority fish species attribute.
F2	Fish Species Range (SPECIES)	Species codes for presence/absence in each watershed derived from GIS overlay of fish species occurrences within broadly defined fish regions for BC. Species ranges were derived from McPhail and Carveth's "Key to Freshwater Fish of BC". 0 = out of species range; 4 = core range; 5 = introduced range; 6 = peripheral range; 9 = estuarine polygons	Yes	Yes	Broader scale than the proposed FSW's attribute, below. May provide a broader/coarser provincial species richness attribute. This has been used in combination with the priority fish species attribute.
F3	Fish Bearing Streams	Salmon and anadromous trout distribution in British Columbia as recorded in the Fisheries Information Summary System. FISS records for all Pacific Salmon Zones were linked to the BC Watershed Atlas.	No	No	Fish Species Range data was used in combination with priority fish species attribute.
F4	Species Richness (ECOLOGICAL)	Species richness is the fundamental unit in which to assess the homogeneity of an environment. Low species richness can also be expressed as a lack of, or reduction, in biodiversity (measure of the health of ecosystems).	Yes	Yes	This metric has been incorporated through the priority fish species attribute.

#	Attribute	Description/Measurement	Meets Criteria	Selected for Project	Comments/Rationale
F5	Salmon Conservation Units (ECOLOGICAL)	Wild salmon to be maintained by identifying and managing "Conservation Units" (CUs) that reflect their geographic and genetic diversity. A CU is a group of wild salmon sufficiently isolated from other groups that, if lost, is very unlikely to recolonize naturally within an acceptable timeframe.	Yes	No	This attribute was seriously considered for inclusion; however time constraints would not allow for further investigation of its value/applicability.
F6	Keystone Species	Keystone species has a disproportionate effect on its environment relative to its biomass. Such a species plays a critical role in maintaining the structure of an ecological community.	No	No	Species of Salmon are considered keystone, however other data sources for salmon available (i.e., Salmon Conservation Units). Also, weak data available for salmon as keystone.
F7	Riparian Classification (Stream Order and Prescribed Setback Combination)	Width of riparian zones determined by attributes of streams, wetlands or lakes, and adjacent terrestrial ecosystems. Use of stream order classification in combination with the six stream riparian classes designated S1 to S6 (through FRPA). Each stream given a stream order class receives a stream riparian classification based on prescribed setbacks for fish and non fish bearing streams.	Yes	Yes	A fairly coarse, yet straightforward disturbance measure based on footprint. Unknown would be the quality of riparian habitat. However, addressing simply as a footprint measure is acceptable.
F8					
F9	Fisheries Sensitive Watersheds (ECOLOGICAL)	Watersheds must meet two criteria: they must have significant fisheries values and watershed sensitivity. Intended to conserve important watershed level attributes protecting fisheries values including natural stream bed dynamics, stream channel integrity, quality, quantity and timing of water flow, and natural, watershed level, and hydrological conditions and integrity. Measured at a watershed level, which can be quantified into hectares or area. Is at ecological scale.	No	No	Could be possibly rolled up with Conservation Units and/or Community watershed attributes. This attribute incorporates data from both provincial and regional data sources, thus implementation across the province does not (yet) appear achievable. May want to re-consider this attribute (or data within) in future attribute refinements.

#	Attribute	Description/Measurement	Meets Criteria	Selected for Project	Comments/Rationale
F10	Community Watersheds	Any natural watershed area on which a community holds a valid water licence issued under the *Water Act* by the Comptroller of Water Rights. Greater than 50 per cent of the watershed area be in Crown Land. The drainage area be less than 500 km^2. There are over 285 watersheds identified throughout the province. They are measured by area (in hectares).	Yes	No	Community watersheds are identified province wide, but require further investigation as to its applicability. More considered a social attribute.
Marine					
M1	Bathymetric Data (Intertidal, Photic, Shallow, Deep, Abyssal)	Seabed depths can be grouped into: intertidal, photic, shallow, and deep water zones. This is descriptive information but inferences can be made as to the relative benthic (seabed) productivity of the different zones.	Yes	Yes	The relationship to benthic productivity has some relationship to the "land cover" category suggested by Bailey et al. (2010)
M2	Protected Areas (Marine Protected Areas, Ecological Reserves, Rockfish Conservation Areas)	Protected Areas include Marine Protected Areas, Ecological Reserves, and Rockfish Conservation Areas. Restrictions on development activities vary for MPAs, ERs and RCAs but energy development will be more problematic in these areas compared to non-designated areas.	4 of 5 – not all MPAs are science based.	Yes	These areas, for a diverse number of reasons are considered valued ecological features. Although energy resource options are specifically excluded from "Protected Areas", it is not clear that all of these marine protected areas are currently identified in BC Hydro data systems
M3	Nearshore features (Shorezone Inventory and Classification)	Near shore Features – Intertidal, shallow subtidal and backshore). The Shorezone database contains comprehensive information for near shore valued ecological features (eelgrass, estuaries, coastal marsh, canopy kelps). This is primarily linear data which will have to be converted to areas using buffer zones.	Yes	Yes	Addresses many of the valued ecological features commonly identified in marine environmental assessment.

#	Attribute	Description/Measurement	Meets Criteria	Selected for Project	Comments/Rationale
M4	Fisheries Harvest Areas (Trawl and Fixed Gear Harvest Areas)	Fisheries Harvest Areas (Fixed Gear and Trawl) expressed as catch or effort within 4x4km grid units.	4 of 5, not science based	Yes	Fixed gear (trap, longline) and trawl fisheries, which harvest from the seabed, are of greatest interest as the fishing areas are relatively static and fishing areas reflect areas of target species concentration. As well these gear types pose the highest risk of fisheries interactions with offshore power generation
M5	Herring Spawning Areas	Herring spawning areas are widely recognized as critical marine habitat areas.	Yes	Yes	A valued ecological feature and one of the most comprehensive "critical habitat" dataset available
M6	Marine Ecological Classification	Marine Ecological Classification (Ecounits) describes marine areas based on wave exposure, depth, subsurface relief, seabed substrate and current.	4 of 5	No	A possible surrogate for "land cover" but based on physical characteristics. Not considered to be easily understood be BC Hydro stakeholders.
	BC and SARA Listed Species	Provincial and SARA listed species information is critical for environmental assessment purposes, but the lack of comprehensive spatial data for listed marine species and the large geographic range of some species (orca) restricts use of this information for planning purposes in the marine environment.	No	No	Although listed species are recognized valued ecological features, comprehensive spatial information on SARA and BC listed species in the marine environment is lacking, limiting the utility of this dataset as an environmental measure
	Marine Bird Areas of Interest	Canadian Wildlife Service compilation of 13 datasets related to marine birds. Considerable overlap with Important Bird Areas (59 of the 68 IBAs are also designated as MBAI	Not assessed	No	Due to the complexity of this data set, and overlap with IBA areas described below, IBAs were chosen to represent valued ecological features for marine birds
	Important Bird Areas	Bird Studies Canada database describing areas of national, continental significance, defined by globally accepted criteria (areas for threatened species, important areas for species with a restricted range, areas of significant aggregations of birds.	Yes	Yes	A valued ecological feature- 68 areas are defined for coastal British Columbia
		Canadian Wildlife Service's mapping of the 442 major coastal estuaries in BC.	4 of 5	Yes	A valued ecological feature providing comprehensive information on BC coastal estuaries when combined with Shorezone estuary mapping,

APPENDIX B
Marine Attribute Tables

Table B-1: Listed Valued Marine Ecological Features (from Lemieux et al. 2007)

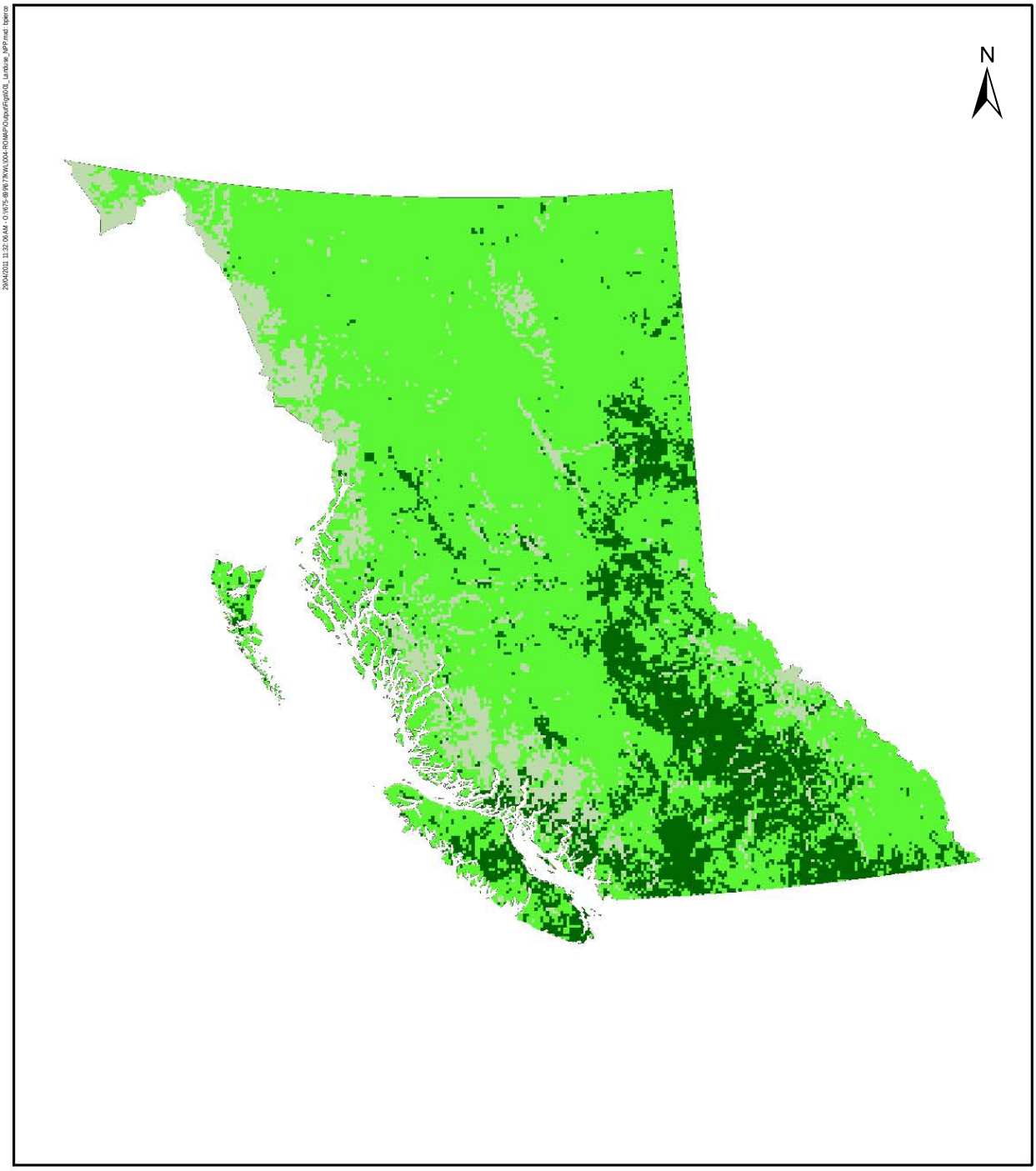
Valued Marine Ecological Feature	Definition	Examples
Current Dominated Channel	Smaller current-dominated channels where land significantly constricts the passage of marine waters leading to relatively fast moving currents. Includes passages, channels, and narrows.[3]	-Outflow of saltwater lagoons -Burnaby Narrows -Skookumchuck Narrows -Nakwakto Rapids
Salt marsh	Coastal wetlands in well sheltered, low wave exposure intertidal areas that are periodically inundated by tidal brackish or salt water and that support significant non-woody vegetation (e.g. grasses, rushes and sedges) and include a high proportion of salt tolerant grasses. Largest dimension should be a minimum of 50 m.	-Fraser, Cowichan and Campbell river estuary marshes -Courtenay area marshes -Delkatla Slough
Tidal flat	Extensive intertidal areas with a slope of less than 5^0 composed primarily of mud and/or sand and are not substantially covered with macro-vegetation such as sea grasses. Largest dimension should be a minimum of 50 m.[4]	-Fraser estuarine complex - Sturgeon and Roberts Banks -Boundary Bay
Eelgrass bed	Species of eelgrass forming an interconnecting system of rhizomes and roots on soft-bottom or hard substrates in low intertidal and shallow subtidal areas. Largest dimension should be a minimum of 50 m.[5]	-Widely distributed in the shallow subtidal zone of inlets all along the coast of BC. -Boundary Bay
Canopy kelp bed	A community dominated by large brown algae, such as bull kelp or giant kelp, in which the kelp forms a surface canopy and is found along the open coast generally between 5 to 30 m water depth.[6]	-North end of Vancouver Island -Juan de Fuca Strait -Nootka Sound and Hesquiaht Peninsula -Estevan Group -Dundas Group
Diverse rocky algal communities[7]	Intertidal and shallow subtidal (to 20m) rocky substrate usually with moderate and higher wave exposures that support a high diversity of red and brown algae with associated invertebrate/animal species.	

[3] Adapted from Dale 1997
[4] Adapted from Dale 1997 and Emmett et al 1998
[5] Adapted from Dale 1997; Emmett et al 1998
[6] Adapted from Dale 1997; Nybakken 1993; DFO 2006
[7] This feature has been defined to encompass rocky reeks and rocky nearshore areas supporting an abundance and diversity of algal and invertebrate species, these areas are also key habitats for rockfish and lingcod

Table B-2: Summary of Marine Spatial Datasets for Coastal British Columbia

Marine Spatial Dataset Initiative	Description	Area	Dataset Source & Links	Example Themes
GeoBC Province of BC	The Province is the key data repository and data portal for the public marine spatial datasets and GeoBC is the main data clearing house Some federal datasets are currently included. A number of 'human use' themes are included, such as recreational use and coastal access points for potential use in emergency response planning. Many of the datasets are available for public download as GIS shape files, directly through the GeoBC website. Others are part of online Atlas and mapped resource summaries.	all BC, coastwide	go to Freshwater and Marine tab at www.geobc.gov.bc.ca Key contact person is Carol Ogborne 250 952 6557 Carol.Ogborne@gov.bc.ca	- fisheries s/a geoduck, crab - resources s/a marine birds, marine mammals etc - BC ShoreZone (in part) - oil & gas themes - human use and shoreline access
BC Marine Conservation Area planning process (BCMCA)	A multi-stakeholder (Fereral, provincial, First Nation NGO) process underway to assemble marine spatial resource datasets for all BC for use as a conservation planning tool. Federal, provincial and community datasets have been collected and are currently being groomed to provide input to a MARXAN model. The process is making use of the BC datasets and has made considerable effort to use all available spatial data.	all BC, coastwide	Dave Nicolson, BCMCA Project Manager 250 857 0444 dnicolson@bcmca.ca www.bcmca.ca	- ShoreZone - all algae & vascular plant surveys - marine birds & mammals - socio-economic
Pacific North Coast Integrated Management Area -- PNCIMA	Initiated by DFO, the planning process is co-sponsored with First Nations. The objectives are to collaborate on marine spatial planning, with compilation of datasets being complimentary to the BCMCA process	North coast, from Campbell River to AK	Steve Diggan Co-chair PNCIMA and Marine Planning Coordinator for CoastalFirstNations group 250 247 8741 sdiggon@coastalfirstnations.ca www.pncima.org/	
WCVI Aquatic Management Board	A marine spatial planning for local communities and First Nation territories is underway on the west coast of Vancouver Island	west coast Vancouver Island	West Coast Vanc Is www.westcoastaquatic.ca	includes database of reports, materials, and online atlas www.westcoastaquatic.ca/RIS.htm
Gwaii Haanas NMCA south coast Gulf Islands NMCA National Park areas of significance planning	Parks Canada has several marine conservation planning processes underway.	Coast-wide but selected areas of focus		
Band Councils and First Nation Communities	Individual bands have active mapping and compilation in their own traditional territories (e.g., Haida Nation, Namgis etc) as well as working with other broader initiatives	Coast-wide but selected areas of focus		
North and Central Coast LRMP processes	The culmination of years of discussion is avialable online through the Provincial GeoBC site, as interactive atlases	North Coast and Central Coast regions		
DFO	Inventories and surveys used for stock assessments:e.g. herring spawn, urchin harvest, geoduck harvest, marine mammals	site-specific or resource specific. Some information from these datasets compiled with BC GeoBC portal		
CWS, Environment Canada	Coast-wide estuary/saltmarsh inventory has been compiled, as well as important bird areas	Coast-wide but selected areas of focus		

APPENDIX C
Attribute Figures



Notes: Source information - Natural Resources Canada, Centre for Remote Sensing 2010

Scale 1:9,000,000

100 50 0 100
Kilometers

Legend

Net Primary Productivity (g C/m^2/yr)

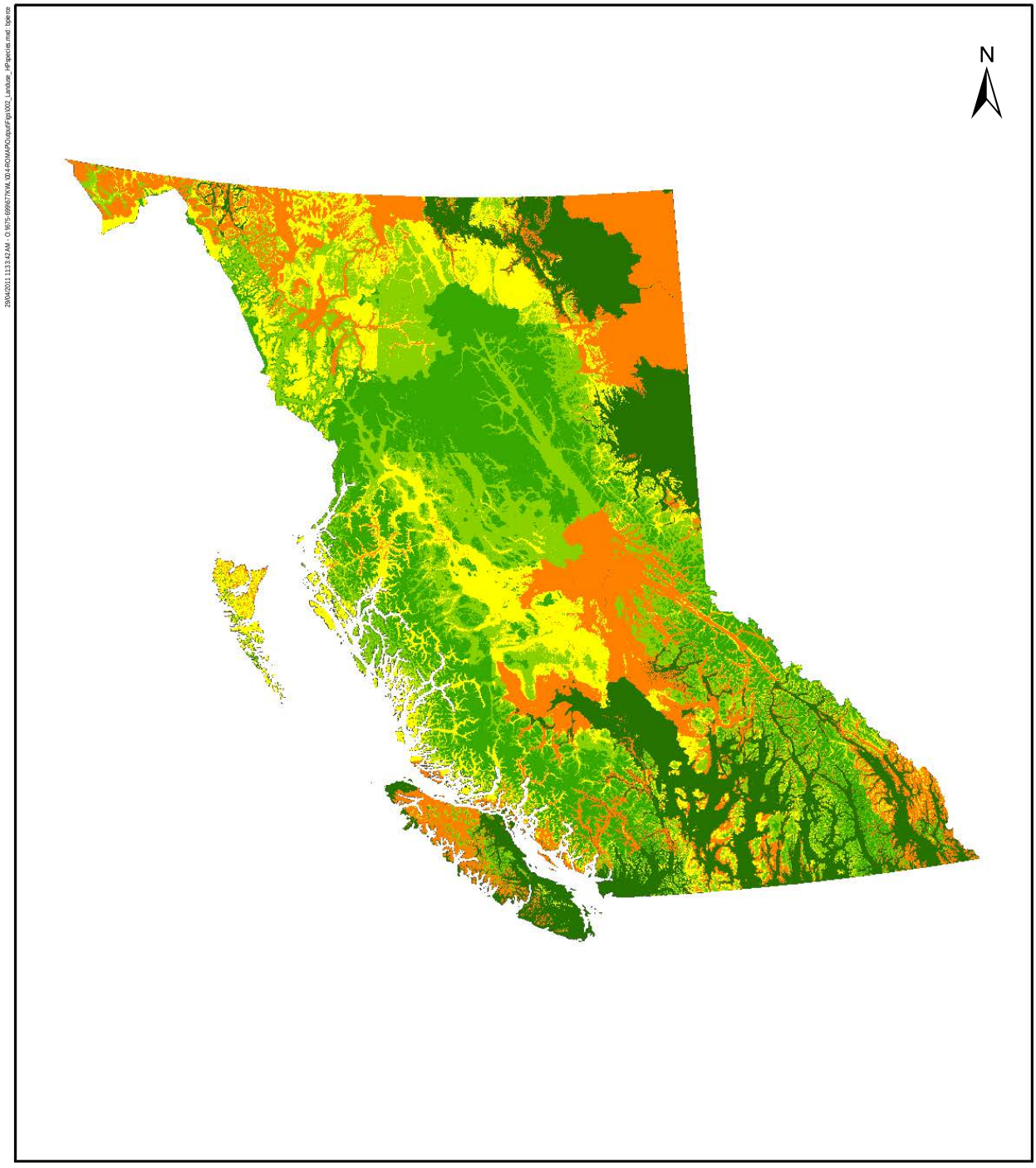
- **Low 0 to 69**
- **Medium >69 to 369**
- **High > 369**

HEMMERA

Review and Update of Environmental Attributes, 2010
Prepared for BC Hydro

Net Primary Productivity

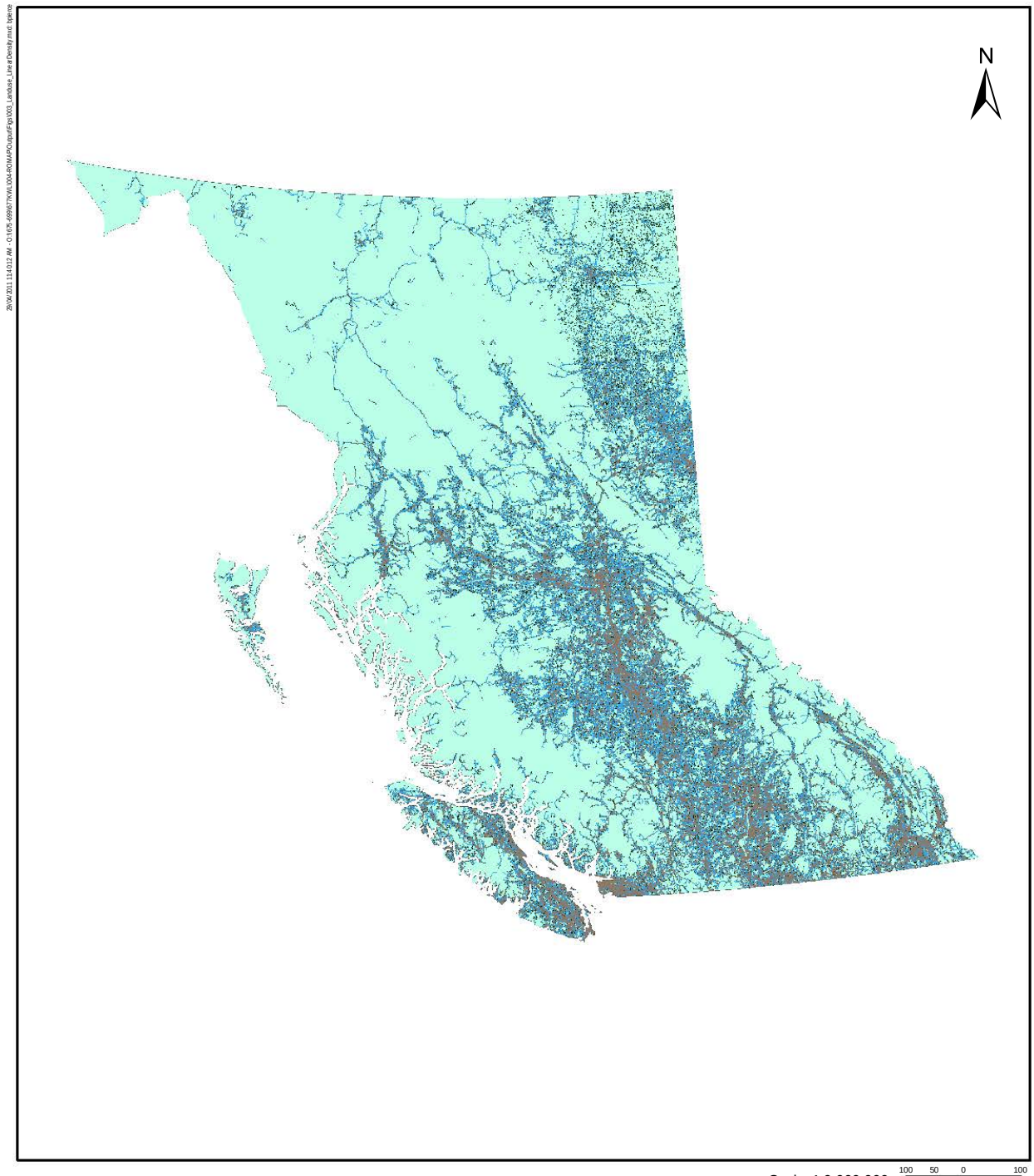
PROJECT No.		
677-004.01	April 2011	FIGURE C1



Notes: Source information - BC Ministry of Environment, Hectares BC 2009. High Priority Species Count Percentiles

Scale 1:9,000,000 100 50 0 100 Kilometers

Legend **Percentile High Priority Species** 0 to 20 >20 to 40 >40 to 60 >60 to 80 >80 to 100	HEMMERA	Review and Update of Environmental Attributes, 2010 Prepared for BC Hydro		
		High Priority Species Indicator		
		PROJECT No. 677-004.01	April 2011	FIGURE C2



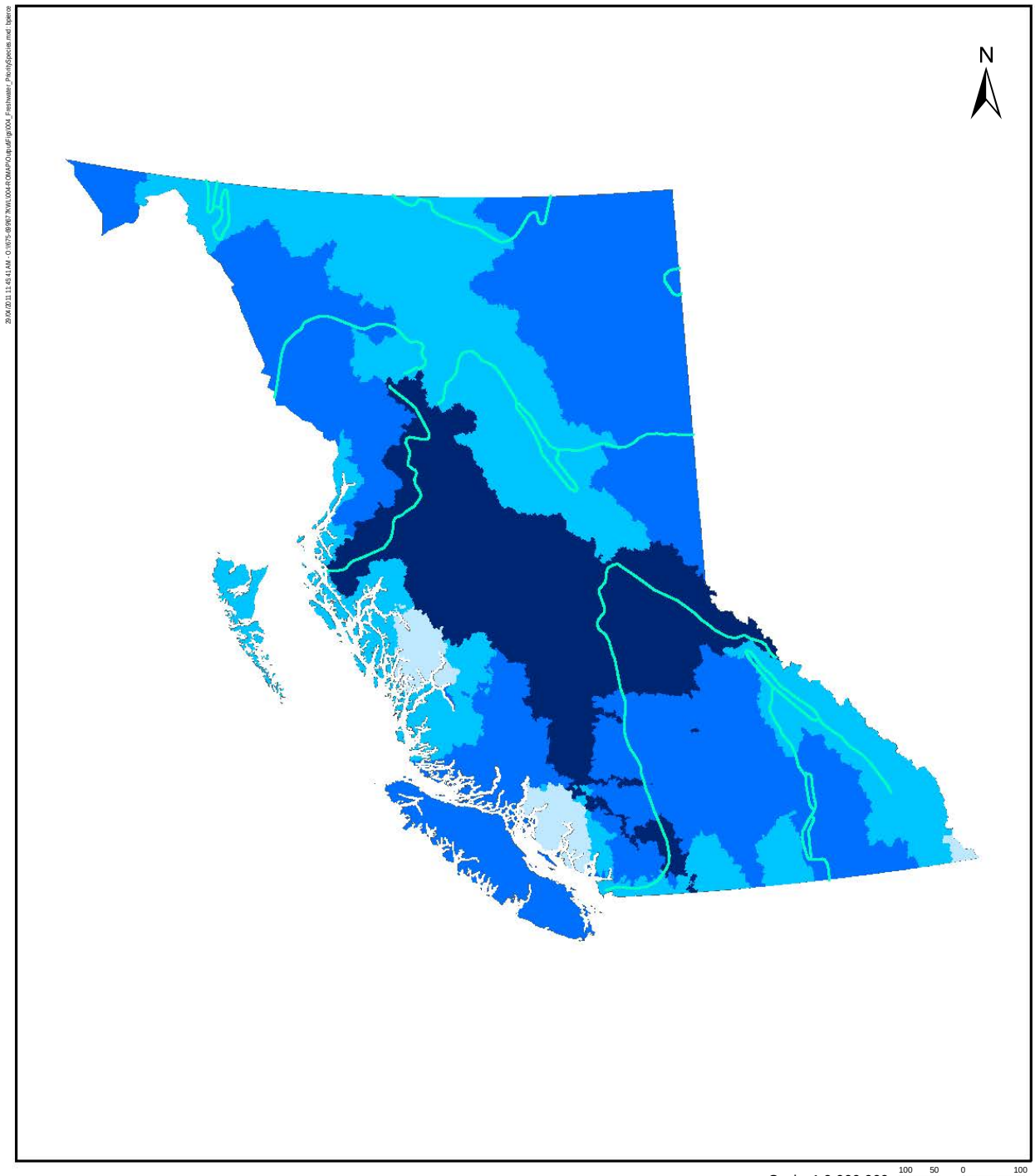
Legend
Linear Density (km/km^2)
- Wilderness <0.2
- Remote 0.2 to <0.66
- Rural 0.66 to 2.2
- Urban >2.2

HEMMERA

Review and Update of Environmental Attributes, 2010
Prepared for BC Hydro

Linear Disturbance Density

PROJECT No.		
677-004.01	April 2011	FIGURE C3



Legend

Grouped Species Count

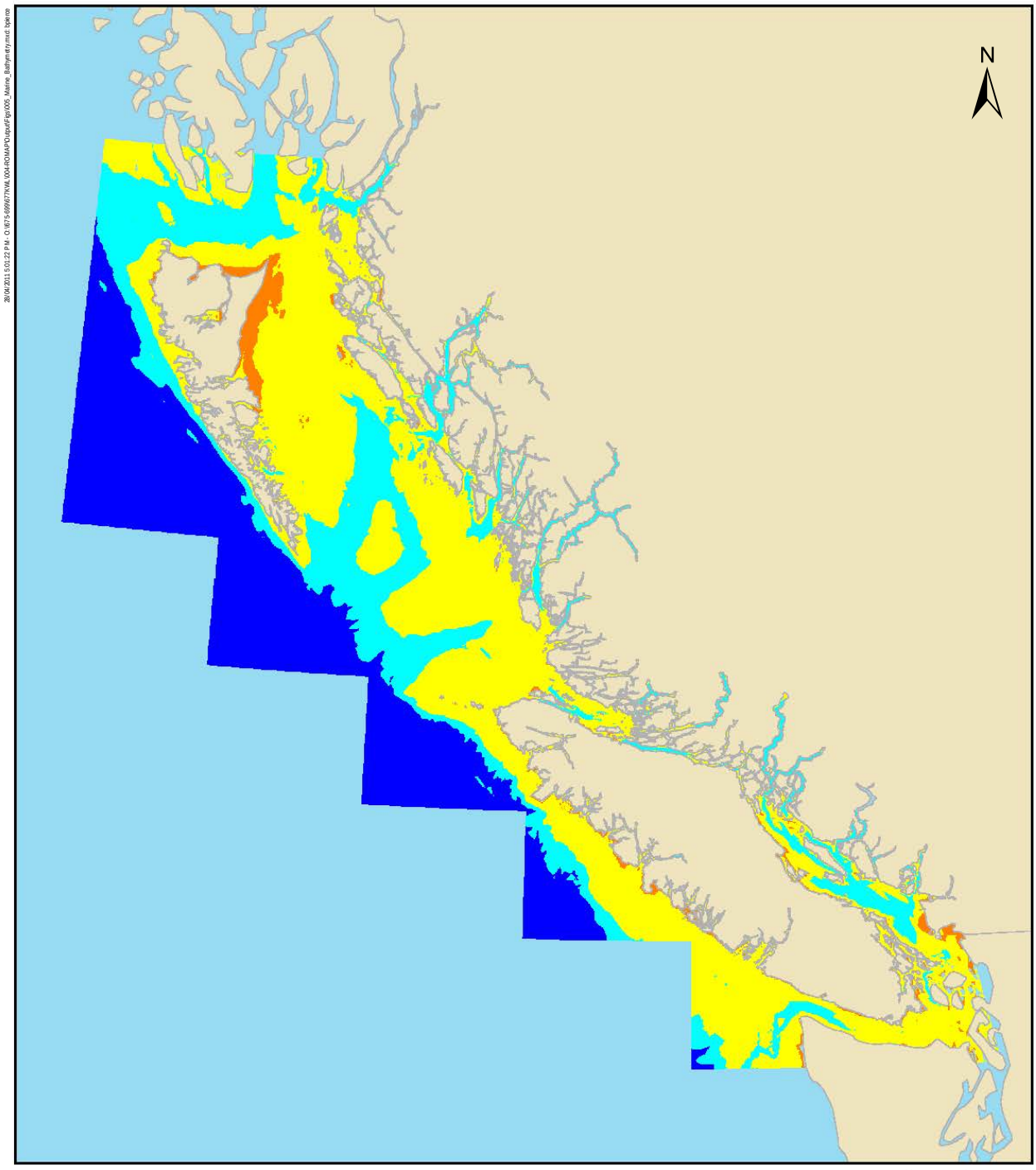
- 1 to 10 Conservation Framework Species
- 11 to 20 Conservation Framework Species
- 21 to 30 Conservation Framework Species
- 31 to 38 Conservation Framework Species
- Major River

HEMMERA

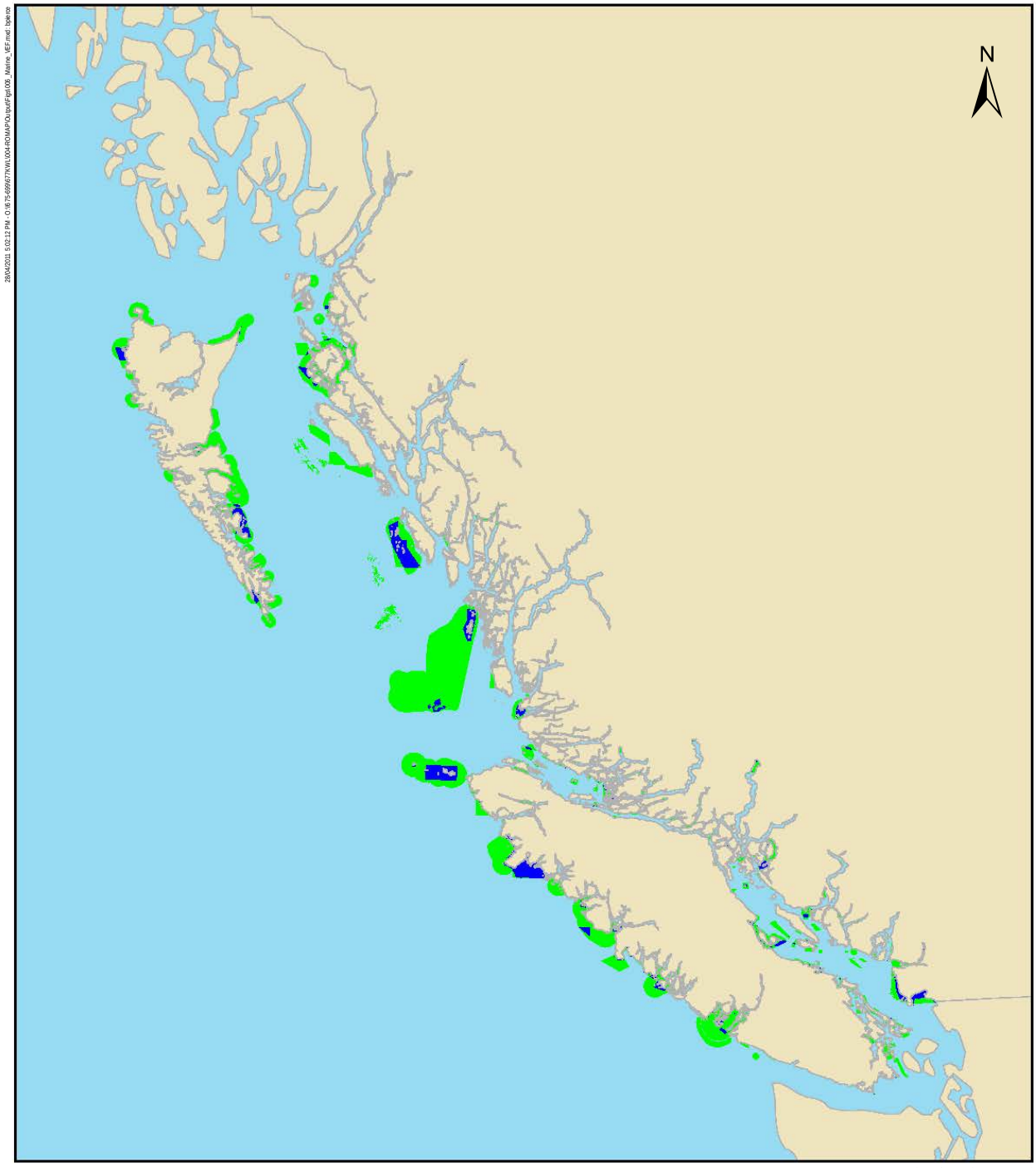
Review and Update of Environmental Attributes, 2010
Prepared for BC Hydro

Priority Fish Species

PROJECT No.		
677-004.01	April 2011	FIGURE C4



Legend **Marine Depth Ranges** Photic 0 to 20m Shallow >20 to 200m Deep >200 to 1000m Abyssal >1000m	HEMMERA	Review and Update of Environmental Attributes, 2010 Prepared for BC Hydro Marine Bathymetry PROJECT No. 677-004.01 / April 2011 / FIGURE C5



Legend
- 1 Valued Feature
- 2 to 3 Valued Features
- >3 Valued Features

HEMMERA

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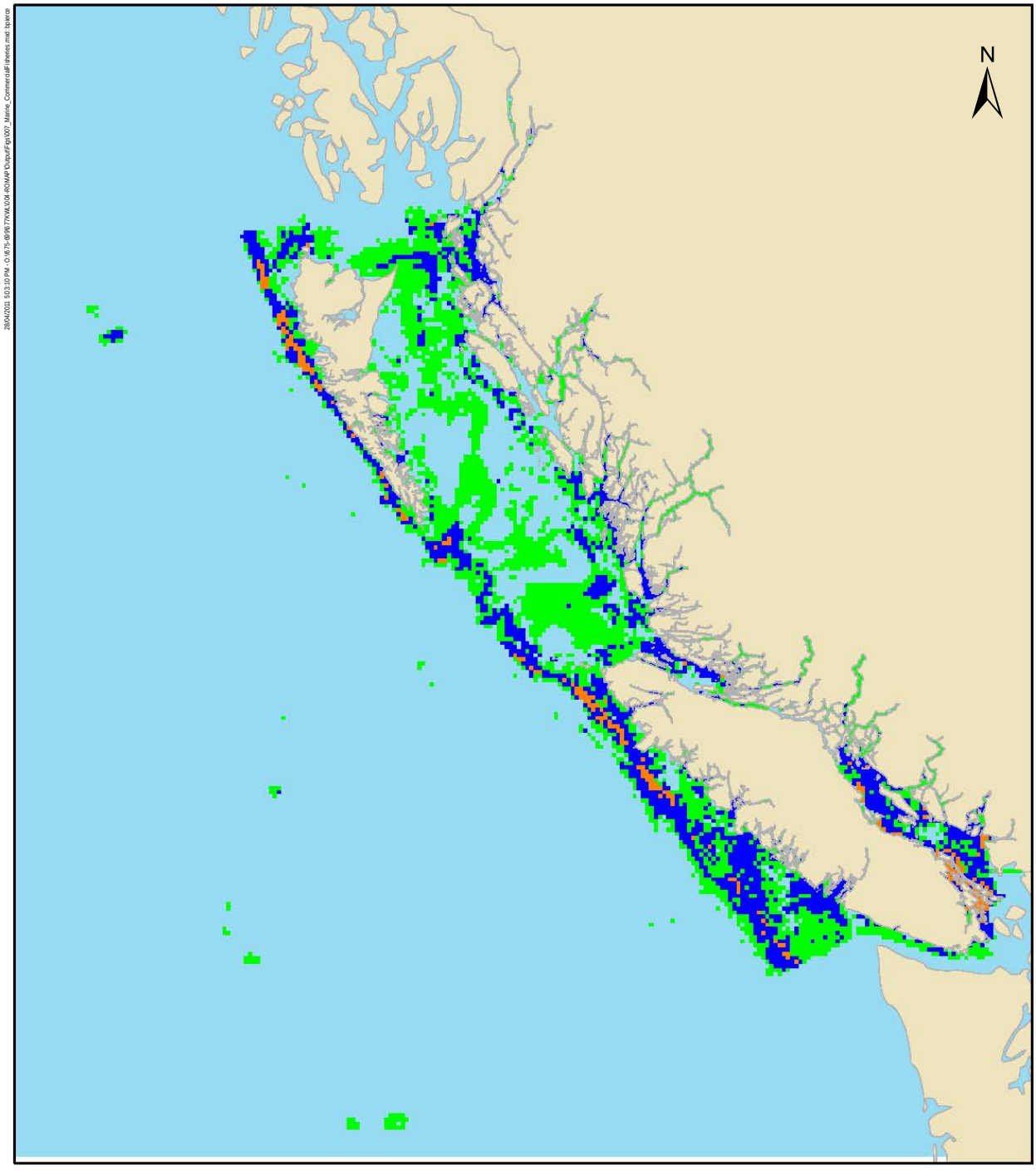
Prepared for BC Hydro

Valued Marine Ecological Features

PROJECT No.		
677-004.01	April 2011	FIGURE C6



Legend
- 1 Bottom Fishery
- 2 to 3 Bottom Fisheries
- >3 Bottom Fisheries

HEMMERA

Review and Update of Environmental Attributes, 2010
Prepared for BC Hydro

Commercial Bottom Fisheries

PROJECT No.		
677-004.01	April 2011	FIGURE C7